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STATIONARY ENGINEERING

BY

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A REFERENCE AND TEXT BOOK

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PREFACE

THE purpose of this book is to present in a compact form those principles which underlie a thorough knowledge of power and heating plants, together with such data on the subject of mechanical and electrical engineering as is deemed essential in the successful operation of power and heating plants of every description.

It has been the object of the author to deal with the subjects herein treated, in a *practical* way as applied to every day work, rather than with theories and mathematical problems.

The name, nature and function of the principal parts of every machine or apparatus have therefore been given before any directions for its operation or use.

Believing that it is impossible for the general reader to fully understand any mechanical device from a mere description of same without the use of a model or an illustration accompanying the description, an unusually large number of full page sectional views of all the devices as described has been included, together with complete specifications for the construction and installation of same, so the reader may fully inform himself upon the construction of every machine or apparatus that he may be called upon not only to operate, but also at times to repair.

Owing to the varied requirements of modern power plants and the high boiler pressures necessary for the operation of modern expansion engines and turbines, the *respon-*

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sibility of the stationary engineer has been vastly increased in the last few years.

When we further consider that many plants now generate their own power for the operation of their lights, motors and elevators, and also do their own refrigeration, it can be seen that the modern stationary engineer must not only be a steam engineer, but an electrical and refrigerating engineer as well.

In fact, the day is not far distant when stationary engineering as a *profession* will be considered as one of the most important branches of engineering, and the *stationary engineer* worthy of the highest reward for his services and well known devotion to his duty.

JOSEPH G. BRANCH.

St. Louis, November, 1906.

SECOND EDITION.

Some typographical and other errors discovered in first edition have been corrected. Two new chapters h been added with twenty new cuts, and five hundred n questions and answers, making this edition contain over thousand questions and answers, fully covering the *en* field of stationary engineering.

JOSEPH G. BRANCH.

St. Louis, April, 1907.

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STATIONARY ENGINEERING

CHAPTER I.

THE STEAM BOILER.

The Steam Boiler.—The steam boiler in its original form consisted simply of a closed spherical vessel partly filled with water, which was heated by a furnace, or by a fire box placed underneath it. This vessel, or boiler as it was called, contained the water to be evaporated into steam, and the furnace, or fire box, contained the fuel to be burned.

From this simple device, first used in a practical way by Newcomen in about 1709, have grown the modern boilers and furnaces, which have made possible the great steam plants of the present day, that are necessary to meet our modern requirements.

A boiler then is simply a vessel constructed for the purpose of generating steam to be used either for power or heating purposes.

Essential Parts.—From their first conception to the present time, all boilers have had the following parts: The vessel, or shell, which contains the water to be evaporated into steam; the furnace, or fire box, in which the fuel is burned, and a chimney to carry away the smoke and gases of combustion, and produce at the same time the necessary draft for burning the fuel. With the boiler and furnace, are various appliances and attachments necessary for the safety and economy of their operation.

Use.—Boilers are used either for **power** or for **heating** purposes, depending upon the character of the work to be performed by them.

Those used for **power** are designated as high-pressure boilers, and furnish steam for the operation of engines and turbines; while those furnishing steam for **heating** purposes in connection with the ordinary heating systems, are designated as low-pressure boilers, they usually being allowed to carry not more than fifteen pounds of steam to the square inch.

Owing to the higher pressure carried on power boilers, they necessarily are constructed much stronger, and differ also in many essential details.

The early types of boilers were constructed exclusively for power purposes, usually for the operation of pumps; the use of boilers for heating purposes being of much more recent date.

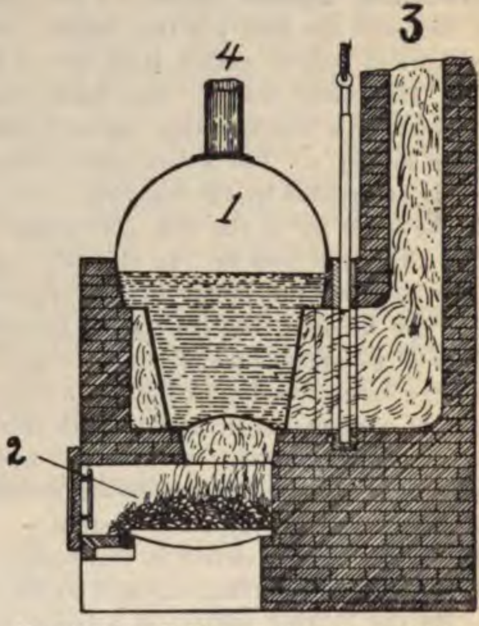
DEVELOPMENT OF THE STEAM BOILER.

In order to thoroughly understand the construction and operation of boilers, one must study their development from their first conception and practical use to the present time. In this way their defects and the improvements made upon them can be more readily understood.

The Newcomen "Spherical" Boiler.—One of the earliest forms was a spherical boiler designed by Newcomen in about 1709. It was constructed of cast iron, and the brick setting supporting the boiler was so arranged that the hot gases from the furnace, which was placed directly under the sphere, passed through a flue which surrounded the boiler just below the water line

e Newcomen "Balloon" Boiler.—A few years later men designed the first practical boiler. It was a l cylindrical boiler, called from its shape, the on" or "Haystack" boiler. This boiler was made ught iron with a hemispherical top and arched bot- s shown in Fig. 1. The steam space necessary in boiler, is designated by the numeral 1, the furnace eath the shell by 2, the flue conveying the hot around this shell and up the chimney by 3, and am outlet from the boiler to the engine, by 4. this, it can be seen that this boiler possesses the sentials of all steam boilers, viz.: a vessel to con- e water; a furnace underneath it and a flue to bring t gases of combustion in contact with this vessel; nt space above the water in the vessel to hold the ; and lastly, a chimney to convey away these gases pply the necessary air for combustion.

efects.—The principal defect in this boiler was the f sufficient **heating surface** exposed to the fire and ases. By the heating surface of a boiler we mean hat portion of the shell which is brought into actual ct with the fire and heated gases, and it is evident eater the heating surface, the greater amount of



The Haystack or Balloon Boiler, Designed by Newcor

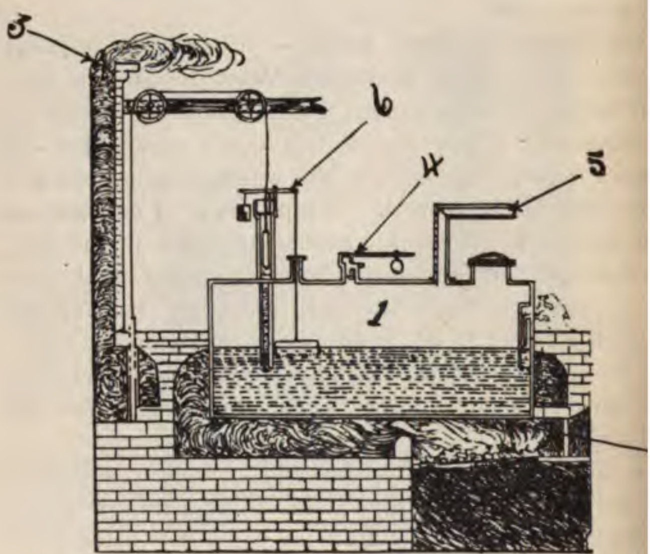
Fig. 1.

steam with the greatest economy, is the most successful boiler, and for over two hundred years it has been the constant endeavor of engineers the world over to produce a perfect boiler, i. e., a boiler in which there will be no loss of heat, but its entire utilization in the work to be performed.

The Watt "Wagon" Boiler.—In order to improve upon the boiler above described, Watt designed a horizontal boiler having a greater heating surface. From its resemblance to a wagon top, this boiler was called the "Wagon" boiler, Fig. 2. The top was hemispherical, and the bottom curved inward. The products of combustion passed from the grate underneath the boiler to the rear, then through the left-hand flue to the front, and from there it passed through the right-hand flue, passing the front of the boiler to do so, finally escaping up the chimney. From the circuit taken by the heated gases first under and then around the shell, this was called the wheel draft.

In the larger sizes, the heating surface was further increased by placing a flue in the boiler through which the gases returned to the front of the boiler after passing to the rear, as in the smaller sizes. The gases, on issuing from the flue at the front, divided and passed to the chimney at the rear of the boiler by flues placed in the brick work on either side.

The travel of the gases was much longer in this boiler than in the "Balloon" boiler, which was a great improvement, as the greater the travel of the gases, the greater is the amount of heat conveyed to the water to be evaporated. Should the heated gases have too short a travel between the furnace and the chimney, they will be permitted to escape up the chimney while retaining



The Wagon Boiler, Designed by James Watt.

Fig. 2.

much of their heat. Such loss of heat means a waste of fuel, and no boiler can be a successful boiler which is so constructed as to permit this waste. In any properly constructed boiler and furnace, the heat of the furnace is about 2,000 degrees Fahrenheit, while the heated gases rarely escape under ordinary conditions above 600 degrees Fahrenheit. This means that there has been 1,400 degrees of heat given up during the travel of the gases. With a properly constructed boiler and under proper conditions the temperature of the chimney gases can be reduced as low as 400 degrees Fahrenheit, but this is rarely done under ordinary conditions. To reduce the temperature of the gases below this point would affect the draft.

Attachments.—Watt used with this boiler a water column in the feed pipe which served as a pressure gauge. The rise and fall of this column not only designated the amount of steam pressure in the boiler, but also controlled the damper which regulated the draft. The feed water was regulated by a float, which, while not now in use, gave to engineers their present idea of automatic boiler feed regulators.

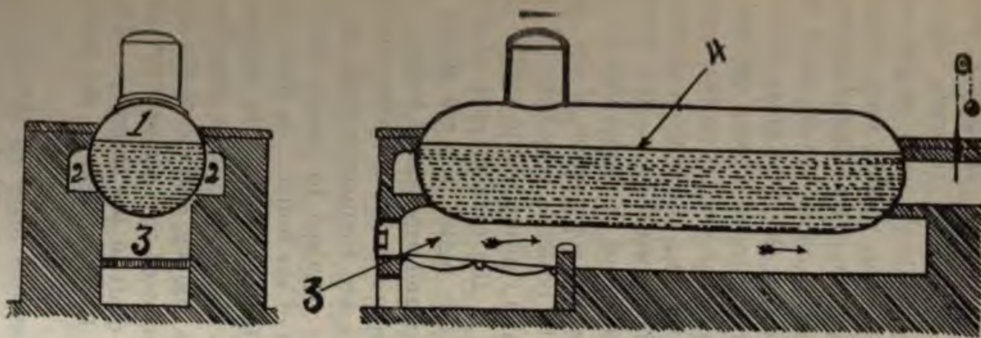
Defects.—The chief defect in this "Wagon" boiler was its **weakness,** owing to its shape and the absence of all stays and braces. For low-pressure purposes, not exceeding 15 pounds per square inch, it was a practical and useful boiler, but for high-pressure work it was entirely unsuitable.

In Fig. 2, showing this boiler, the numeral 1 is the shell, 2 the furnace, 3 the chimney, 4 the safety valve, 5 the steam outlet to the engine and 6 the automatic pressure gauge and damper regulator.

"Cylindrical" Boiler.—Watt's "Wagon" boiler was succeeded about the beginning of the present century by the first of the **modern** type of boilers. This was the plain "Cylindrical" boiler made of wrought iron, with flat or hemispherical ends, known as the "Egg end" boiler. The egg shape of the ends of this boiler greatly increased its strength over that of the "Wagon" boiler, the principal defect of which was its **weakness.**

Defects.—Owing to the shape of this boiler no staying is required, its form, with the exception of the sphere, being the strongest to resist rupture. The heating surface is small, unless the boiler is made very long, which is a decided disadvantage. All the sediment collects in the bottom of the shell where the heat is the greatest, which soon causes the plates to burn, and also prevents, together with the scale which soon forms, the proper conduct of the heat to the water. These boilers are necessarily small of diameter, being from 30 to 42 inches, and quite long, being from 20 to 50 feet, and are extremely wasteful of fuel. They can therefore for this reason be only used in places where fuel is abundant, as in mining districts, and around blast furnaces.

This boiler is shown in Fig. 3. The numeral 1 is the shell, the ends being set horizontally in brick work. The lower part of this cylinder contains the water, the upper part the steam, 2 the flues on each side of the shell, 3 the furnace outside the cylinder, which consists simply of grate bars set in the brick work at a convenient distance below the bottom of the shell. The fuel is throw' on the bars through the fire door which is set in tl front brick work. The air necessary for combustion e ters between the grate bars from below through the a pit. The flame and hot gases pass over the bridge



The Cylinder Boiler.
Fig. 3

close under the boiler, thence along the flue to the rear, returning to the front through the flue on one side of the shell and back again on the other side to the far end of the boiler, whence they escape up the chimney. Numeral 4 is the water line of boiler.

This boiler is a great improvement upon the earlier types of boilers, but has the two great defects above named, viz.: the lack of proper heating surface, and the deposit of solid matter of the water on the highly heated portion of the shell forming the bottom of the boiler.

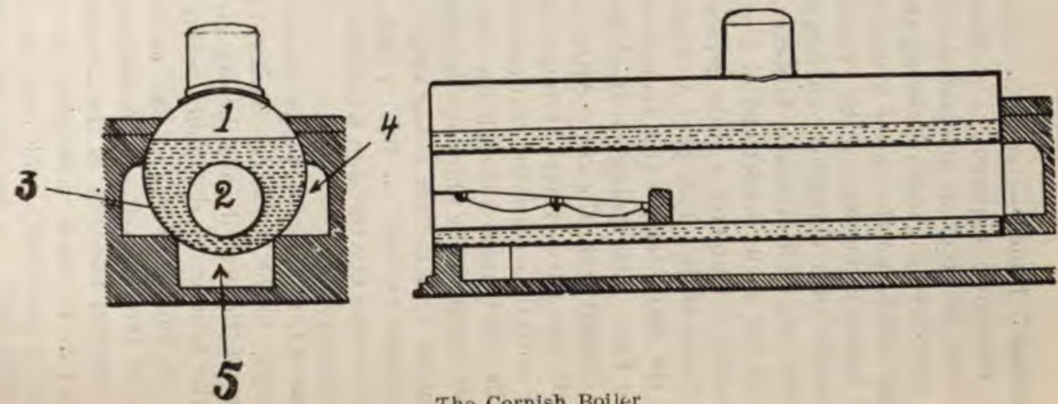
In addition to these two defects, also, owing to the difference in temperature of the gases due to their long travel, the expansion and contraction of the metal composing the shell of the boiler is very unequal, producing cracks in the metal and rupture of the joints. While the travel of the gases in the earlier types of boilers was much too short, in this boiler it is too great, owing to the three turns under and around the boiler, which they are forced to take before escaping up the chimney.

As these boilers are frequently made 40 feet long, the gases would be required to travel 120 feet before reaching the far end of the boiler. As their temperature on starting at the forward end of the boiler would be about 2,000 degrees Fahrenheit, after traveling 120 feet in contact with the cooling surface of the boiler, they would be at times reduced to a temperature barely sufficient to produce a draft in the chimney. The effect of this was to highly heat one end of the boiler, leaving the other end cold.

This boiler possesses many of the requirements of the modern boiler, and it should therefore be thoroughly understood before beginning the study of the more modern types.

The "Cornish" Boiler.—Upon the defects of the above boiler becoming apparent, a Cornish engineer named Trevithick, in order to increase the heating surface of same, conceived the idea of placing the fire **inside** an **internal flue** which ran the entire length of the shell. This type of boiler is known as the "Cornish boiler," Fig. 4. It consists of a cylindrical shell with flat ends as shown in the cut. The furnace, however, instead of being outside of the shell, is **enclosed** in a second cylinder or flue having a diameter a little greater than half of that of the boiler shell. This gave an additional heating surface of the entire length and diameter of this second cylinder or flue. The arrangement of the grate and bridge wall is evident from the cut. After passing over the bridge wall, the gases travel through this internal cylinder or flue until they reach the rear end of the boiler, returning to the front again through the two side flues, and thence back again to the chimney through a bottom flue. The numeral 1 in the cut is the outer cylinder or shell, 2 the internal cylinder or flue, 3 and 4 the side flues, and 5 the bottom flue through which the gases pass finally to the chimney.

Advantages.—This type of boiler removed one of the chief objections to the "Cylinder" boiler, by reducing the temperature of the heated gases before they came in contact with the bottom of the boiler where the sediment collects. It further increased the amount of the heating surface of the boiler by an amount equal to the surface of the internal flue, but as the diameter of this internal flue had to be made sufficiently large to contain the furnace, it practically prevented the making of this boiler in small sizes. It was the first type of what is known as the **internally fired boiler.**

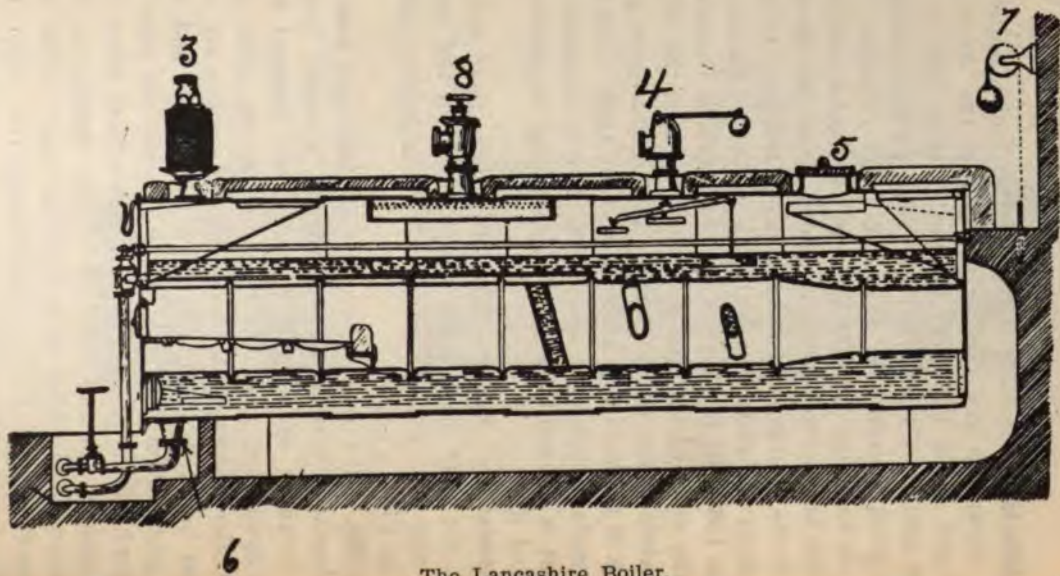


The Cornish Boiler.
Fig. 4.

Defects.—The chief defect of this boiler is the unequal expansion and contraction due to the use of the outer and inner cylinder; as the internal flue is the hottest portion of the boiler, and consequently undergoes much greater expansion than the other cylinder. The result is to bulge out the ends of the boiler, and then when the boiler cools down, or is out of use, the flue contracts to its regular size, and thus has a tendency to work loose from the ends to which it is riveted. Should the ends be too rigid to move, a serious strain is thrown on both the ends of the flue and the heads of the boiler. Even while in use the flue of this boiler undergoes great changes in temperature, according to the state of the fire. This constant expansion and contraction so weakens the flue that it frequently collapses, resulting in great disaster and loss.

"Lancashire" Boiler.—To rectify these most serious defects, the next step in the development of the steam boiler was the production of the Lancashire boiler, shown in Figs. 5 and 6.

In this boiler it will be observed there are two internal furnaces instead of one, as in the "Cornish" boiler. These furnaces usually emerge into one internal flue, though sometimes each flue continues to the other end of the boiler as a separate flue. These furnaces are supposed to be fired alternately, and the smoke and unburned gases from the fresh fuel in one flue are aided in their combustion by the hot air proceeding from the other furnace. In this way all violent changes in the temperature are avoided, as well as the waste of fuel due to unburned gases. In the cuts showing this boiler, the numeral 1 is one of the internal furnaces, and 2 indicates what are known as the Galloway tubes.



The Lancashire Boiler.
Fig. 5.

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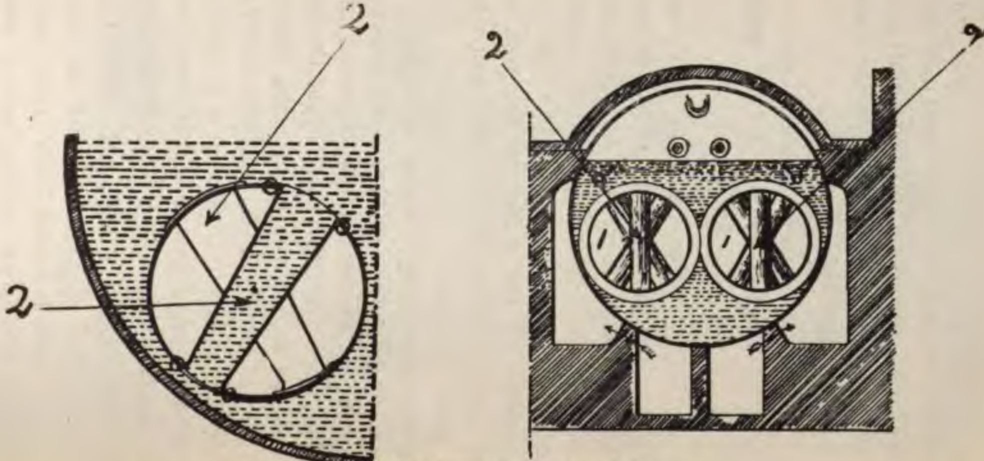
"Galloway" Tubes.—These tubes are connected across the flues as shown in Fig. 6, and not only contribute to strengthen the flues, but they add greatly to the heating surface, and greatly promote the circulation of the water to be evaporated.

These Galloway tubes were the first step towards the development of what is known as the **water tube** boiler.

In order to fully realize what an important step these tubes form in the development of the steam boiler, it is sufficient to say that there can be no steam evaporated from water in any useful quantities, where there is no **circulation** of the water itself. It is the rising of the heated particles of the water to the top, and the descent of the cooler ones to the bottom upon which the formation of steam depends. It is therefore absolutely necessary that there be some circulation of the water in all boilers, and the efficiency of the boiler depends to a great extent upon the proper circulation being afforded. The greater the circulation, the more rapid the evaporation, and, to a large extent the greater the efficiency of the boiler. The Lancashire boiler was the first boiler in which an attempt was made to secure a proper circulation, and while the method pursued was most primitive, it marked a great advance in stationary engineering.

The Lancashire boiler fitted with these Galloway tubes is shown in Fig. 5, together with the numerous boiler attachments, which added both to its safety and economy. The cut represents a longitudinal section of the boiler together with these fittings. There are two safety valves shown on top of the boiler, one being 3, which is of the dead-weight type and which will be de-



Section of Galloway Tubes and Furnace.
Fig. 6.

scribed hereafter; and 4, being a low-water safety valve. This last valve is operated by means of a lever and rod which are attached to a float, which rests on the surface of the water. Upon the water sinking below its proper level, the float also sinks, causing the valve to open, thus allowing steam to escape and giving an alarm. 5 is the manhole with its cover plate, which manhole admits of access to the interior of the boiler. 6 is the mud hole through which the sediment accumulating along the bottom of the boiler, is raked. 7 is the damper and 8 the steam outlet. On the front of the boiler are attached the pressure gauges, the water gauges, and the furnace door, as well as the feed pipe and the blow-off pipe. There are also two iron doors by which access may be gained to the two lower external flues for cleaning purposes.

Advantages.—The Galloway, or Lancashire boiler, as it is variously called, is considered a most economical boiler, both in this country and in England. A great many exhaustive tests and experiments have been made with this boiler, and its great worth is universally recognized.

Defects.—The disadvantage of this boiler is the difficulty of securing adequate space for the two furnaces without unduly increasing the diameter of the shell. Where the furnaces are **too small,** there cannot be complete combustion owing to the cold crown plate of the boiler coming in contact with the heated furnace; while the narrow space between the fuel and the crown sheet does not permit of the proper quantity of **air** being supplied above the fuel necessary for perfect combustion.

MODERN TYPES OF BOILERS.

Modern Boilers.—The development of the modern types of boilers from the Lancashire, or Galloway boiler, was but a short step.

It was soon found that the placing of an internal flue in the shell not only greatly increased the heating surface, but added to the strength of the boiler, so additional flues were added; and as the number of the flues were increased it became necessary to **decrease** their diameter, until finally the present types of horizontal tubular boilers were produced.

Upon decreasing the diameter of the flues, they soon became too small to be used for furnace purposes, and the furnace was then placed on the **outside** of the shell, making the boiler an **externally** fired boiler.

From the placing of the furnace either **inside** or **outside** of the shell, all steam boilers are divided into **two** principal classes, viz.: (1) Internally fired boilers, and (2) Externally fired boilers.

Classes of Boilers.—All steam boilers are **further** divided into two classes according to the **course taken** by the gases after leaving the furnace; one class being composed of (1) **shell or fire tube boilers,** in which the hot gases pass **through** the flues or tubes, thus heating the water which surrounds them; while the **second class** are composed of (2) **water tube boilers,** in which the gases pass **around** the flues or tubes, and in this way heat the water which **fills** the tubes.

Multitubular Boiler.—The continual increase of the number of flues, or tubes as they are called when less than 6 inches in diameter, developed what is known as

the **multitubular** or **return tubular boiler,** in which there are as many as 130 3-inch tubes, or 84 4-inch tubes.

While the number and diameter of these tubes vary, the following number and sizes are generally used in boilers of this type, under ordinary conditions.

Number of Tubes Usually Put in Return Tubular Boilers.

HAND-HOLE UNDER TUBES.					MAN-HOLE UNDER TUBES.			
Diam. Boiler.	2½ in. Tubes.	3-in. Tubes.	3½-in. Tubes.	4-in. Tubes.	Diam.	3-in. Tubes.	3½-in. Tubes.	4-in. Tubes.
36	38	26	..	..	..	..	..	..
42	52	38	..	..	42	..	22	18
44	..	38	34	22	44	28	26	20
48	..	52	38	34	48	44	28	26
54	..	54	44	34	54	56	44	36
60	..	82	64	54	60	62	54	44
66	..	..	72	54	66	88	66	54
72	..	..	92	72	72	124	86	70
..	..	..	..	..	78	132	100	84

This type of boiler is illustrated in Figs. 7 and 8, the last being a longitudinal cross-section of same.

It is the most popular form of boiler in general use, possessing many advantages over all other types, the first of which is its **cheapness.**

Advantages.—Its principal advantages are its steady steaming qualities, its durability and adaptability to any class of work.

Its **Principal Disadvantages.**—(1) Its lack of safety;

(2) Its slow steaming qualities, owing to the large body of water to be heated;

The Horizontal Flue Boiler.
Fig. 7.

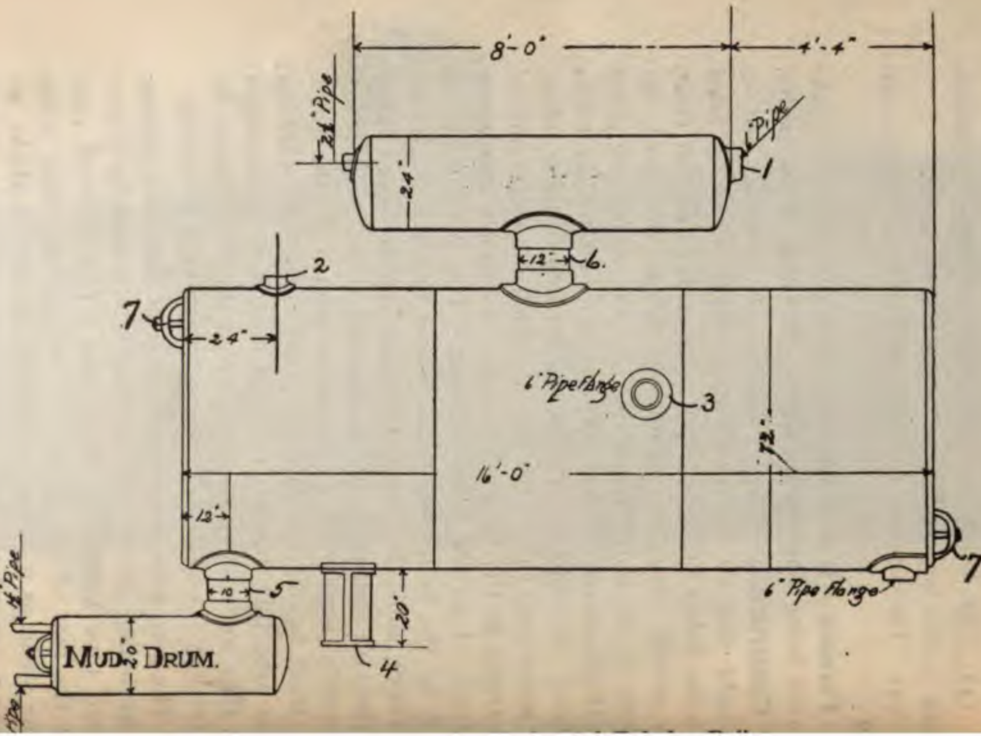
(3) The liability of the tubes or flues to rupture, owing to the large diameter necessary for same;

(4) The amount of space necessary for boiler setting.

Furnace.—It is usually an externally fired boiler, the furnace being entirely **outside** of the shell of the boiler.

Construction.—The boiler itself consists of a wrought iron or steel cylindrical shell, which is filled with the tubes or flues terminating in the two flat ends, into which they are expanded. About one-third the volume of the boiler is occupied by the steam, the other two-thirds being the water space in which are the tubes or flues. In order to prevent the **burning** of these tubes, the water line, that is the line at which the water should be carried in the boiler, is about two inches **above** the top row of all the tubes or flues. The portion of the heads of the boiler below the water line are stayed by the tubes, while that above the water line is stayed either by through stay rods, or by diagonal stays. The boiler is usually supported by brackets riveted to the shell. The front brackets are usually fixed in the side walls on either side, but the rear brackets should be so arranged that they move upon rollers, so that the shell cannot be strained by the expansion and contraction of the plates.

The feed pipe may enter either at the front or rear of the boiler, but it should always terminate in a perforated pipe **below** the water line. The blow-off pipe is at the rear of the boiler, this being the lowest point of the shell, as a boiler is usually set with a slight inclination toward the rear so that the sediment will collect near the blow-off pipe. This pipe is also often used to blow out sediment, and to empty the boiler.



8'-0"
4'-4"
2½" Pipe
6" Pipe
1
24"
12"
6.
2
7
24"
6" Pipe Flange
3
72"
16'-0"
12"
10
5
20"
4
7
6" Pipe Flange
MUD DRUM.

Heating Surface.—In this type of boiler, the heating surface is composed of about **one-half** of the shell, together with the inside of all the tubes or flues, and about **two-thirds** of the two ends or tube sheets, as these surfaces come in contact with the fire and heated gases. It is therefore seen that all the heating surface is **below** the water line.

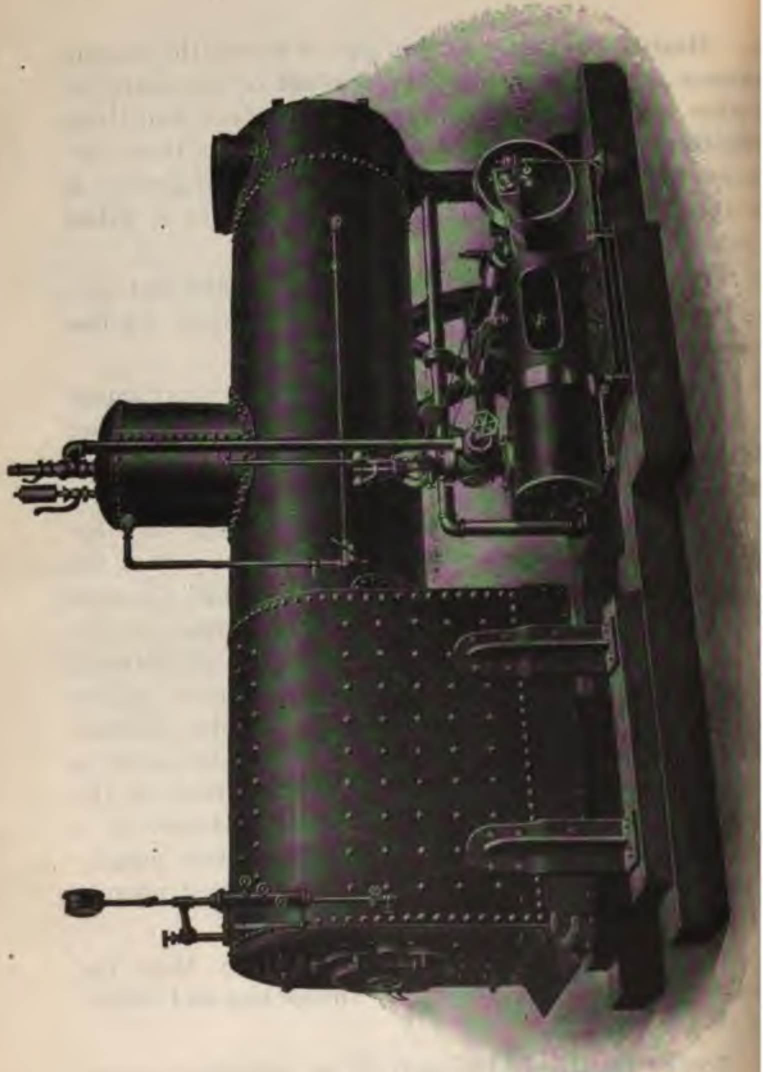
Fig. 13 is a cross-sectional view of a flue and of a multitubular boiler, in which 1 is a cross-section of a **flue boiler**, and 2 that of a **tubular boiler.**

Locomotive Boiler.—Next to the multitubular boiler, the locomotive boiler is used in this country more than any other type. It is used exclusively on railroads, and is also largely used as a stationary boiler.

Construction.—The general construction of this boiler is shown in Figs. 9 and 10. The front part of the shell is cylindrical, while the rear part which contains the furnace, is of a rectangular shape. A space is left between the sides of the shell and the end of the furnace, which space is filled with water and is known as the "water leg" of the boiler. A number of tubes extends from the front sheet of the furnace, or fire box as it is called in this type of boiler, to the front head of the shell. The boiler is supported at the front end by a cast-iron cradle which rests upon a foundation usually made of masonry. The rear end is supported upon a brick wall, which also forms the ash pit.

The gases of combustion pass directly from the furnace through the tubes to the smoke box and thence out of the stack.

Forced Draft.—In locomotives on railroads a forced draft is produced by causing the *exhaust* steam from



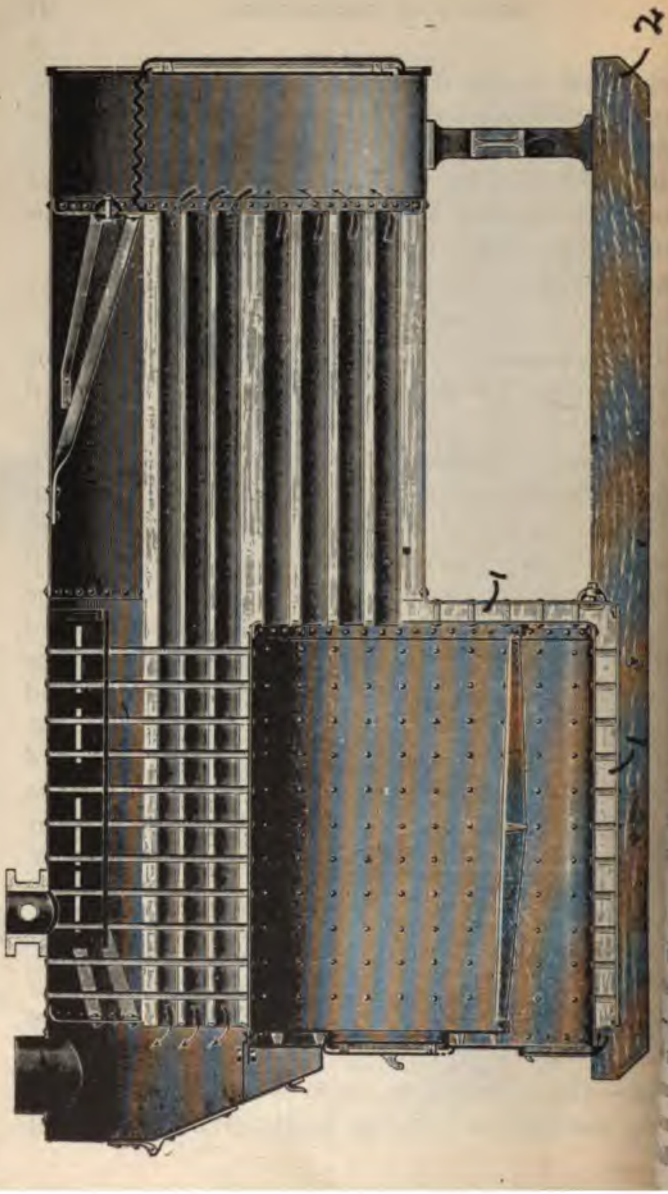
the cylinders to be discharged into the chimney by means of a pipe called the blast pipe. At each discharge of exhaust steam escaping up the chimney it forces the air out in front of it, causing a partial vacuum, which can only be supplied by the air rushing through the furnace and the tubes, thus causing the draft.

Advantages.—The chief advantages of this boiler are its economy and its ease of installation.

Disadvantages.—Its disadvantages are, the trouble of keeping clean and inspecting it, and the difficulty of repairing same.

The Vertical Boiler.—This type is simply a modification of the locomotive boiler placed on end. A common form of the vertical fire tube boiler is shown in Figs. 11 and 12. This boiler consists of a cylindrical shell having an internal circular fire box or furnace. The ends of the tubes are expanded into the upper head of the cylindrical shell, and at the bottom into the top, or crown sheet of the furnace. The grates are supported by rings riveted to the internal wall of the fire box. The top of the boiler is made dome shape, in the center of which is placed the chimney, which is formed of the usual wrought iron plates. The furnace, which is placed at the bottom of this shell, is entirely surrounded by water, except the bottom in which is placed the grate. The connection of the tubes determines whether the boiler is (1) A through tube boiler as shown in Fig. 11, or "Dry top," as it is sometimes called; or, (2) A submerged-tube boiler, as shown in Fig. 12. The latter type is preferable, but more expensive.

Use.—These boilers are used where floor space is valuable, and there is sufficient height. While in general



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they are not as economical as other types of boilers, they are becoming more universally used owing to their many other good qualities.

Principal Advantages.—(1) Entirely self contained.

(2) The small amount of floor space required.

(3) Ease of installation.

(4) Portable character, permitting them to be removed from one place to another with ease and dispatch.

(5) Their extreme simplicity.

(6) Their low cost, and durability.

Principal Disadvantages.—(1) Their lack of safety.

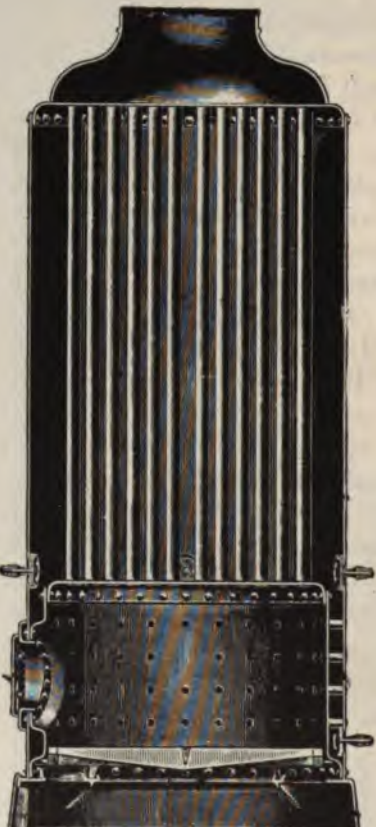
(2) Waste of fuel owing to short travel of the gases, and lack of proper circulation.

Water Tube Boilers.—Figs. 13, 14, 15 and 16 illustrate common types of water tube boilers. In such a boiler the water circulates through a series of tubes of comparatively small diameter, which communicate with each other and with a common steam chamber. The flames and hot gases are made to circulate between them, and are usually forced by baffle plates or walls, to be made to act equally on all parts of the tubes before being allowed to escape up the chimney.

While there are many varieties of this type of boiler, the above description constitutes the essential principles of them all.

In the best forms of these boilers, they are suspended entirely independent of the brick work from wrought iron girders, resting on iron columns.

Advantages.—(1) Safety from explosions, owing to the contents of the boiler being divided up into small portions throughout the water tubes, water legs and steam drums. Should there be a rupture in the tubes, or any part of the boiler, only the immediate contents will



Sectional View of a Vertical Fire Tube Boiler.
Fig. 11.

be liberated, instead of the entire mass of water and steam.

(2) The tubes being of much smaller diameter than would be necessary if they were only a few in number, they can be made much smaller and hence stronger, and therefore less likely to rupture.

(3) Owing to their contents being held in small portions, instead of in a large mass of water, they possess quick steaming qualities.

Disadvantages.—(1) They require more masonry for their setting, and occupy more space than shell boilers.

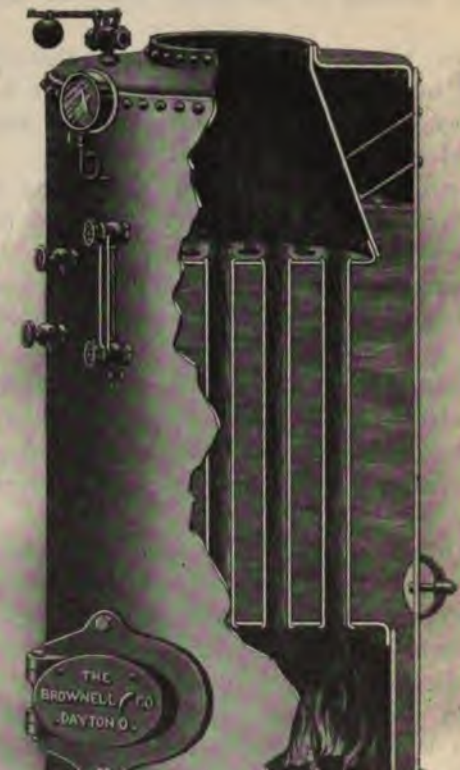
(2) Owing to the water being held in small quantities, irregular firing is apt to cause a violent generation of steam, producing sudden fluctuations of pressure, which may result in priming and thereby overheating the tubes.

(3) While this type of boiler is very susceptible for cleaning, the scale which forms in the tubes at times becomes very difficult to remove.

The Internal Furnace Boiler.—The types of boilers heretofore described have all been Internal Furnace Boilers, with the exception of the Horizontal Return Tubular and Water Tube Boilers, but none of them are designated by the character of their furnace alone.

Figs. 17, 18 and 19 illustrate on the contrary what is known as the Internal Furnace Boiler, the character of the furnace being its most prominent feature.

Advantages.—The chief advantage of this type of boiler for ordinary work, is the economy of first cost, they being "self contained," that is, they are independent of any masonry setting, cast-iron fronts, buckstays, tie rods, etc., therefore they require but little founda-



A Vertical Fire Tube Boiler With Submerged Tubes
Fig. 12.

tion, and are susceptible of being easily removed from one location to another.

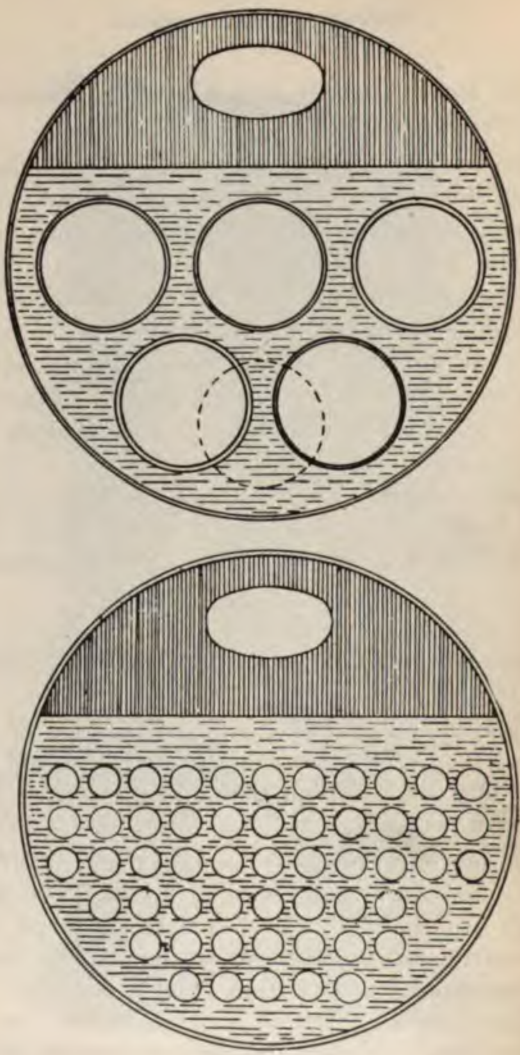
They are also capable of carrying an extremely high steam pressure and are at the same time steady steamers. Owing to the furnaces being entirely surrounded by water, the heat of combustion is utilized to a greater extent than is practical with external furnace boilers. These boilers are extremely economical in the consumption of coal, not only for the above reasons, but owing to the absence of all brick setting, which settings usually crack and allow the heat to escape, and the cold air to enter the furnace and combustion chamber.

Disadvantages.—The principal disadvantages of this type of boiler is the short travel of the gases, thereby permitting them to escape at too high a temperature up the stack.

The circulation is also defective owing to faulty construction, and the improper distribution of the heating surface.

Dry Back.—This boiler is a modification of what is known as the Clyde or Scotch Marine Boiler and is often called a **Dry Back Scotch Boiler** from the fact that the combustion chamber is not surrounded by water.

The Marine Boiler.—This boiler as illustrated in Fig. 20, consists of a large cylindrical shell (1), the ends of which are closed by flat heads (2), a large flue (3) of the corrugated type, known technically as the **Morison Suspension Furnace Flue**, extends the entire length of the boiler and is securely riveted to the two heads, which are flanged inward. Above and around this large flue and below the water line is a nest of tubes (4) which extend from head to head. The front ends of these tubes open into a smoke box (5) *that connects with* the chim-



Cross Sections of Horizontal Flue and Tubular Boilers.
Fig. 13.

ney or stack (6). The flat heads are stayed by the through rods (7) which are in the steam space, and which prevent the deflection of the heads.

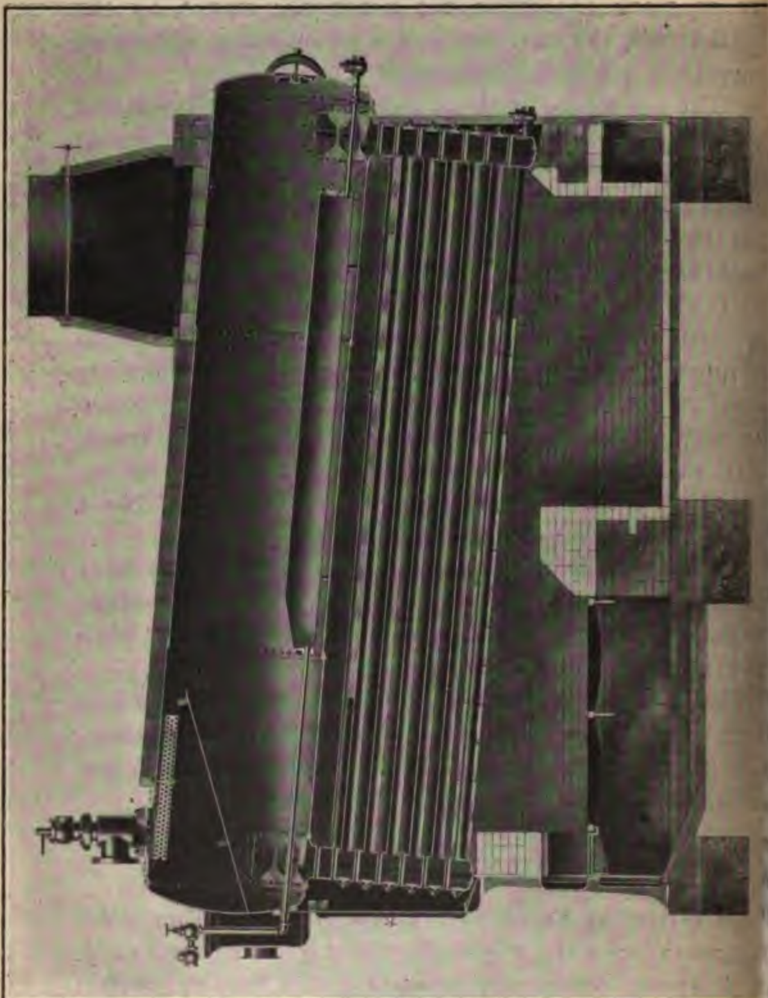
The remaining parts of the flat heads are supported by the tubes, which are first expanded and then beaded over, and also by the furnace flue. The furnace (8) is placed within the furnace flue and consists of the usual grate (9), ash pit (10) and bridge (11). The gases of combustion flow to the rear into the combustion chamber (12), and then pass through the tubes to the front and into the smoke box. The sides of the combustion chamber are stayed to each other and to the shell plate of the boiler, forming a water chamber or back between the combustion chamber and the shell of the furnace (13), making it a "Water back" boiler, which is the essential difference between it and the "Dry back" boiler used exclusively for stationary work.

Marine boilers over 9 feet in diameter usually have two furnaces, those over 14 feet, three furnaces, while the largest boilers used on first-class mail steamers, often exceeding 15 feet in diameter, have four furnaces.

Summary.—All boilers can therefore be divided into three classes, viz.: Stationary, Locomotive and Marine; and these into six types, viz.: Flue, Tubular, Water Tube, Locomotive, Vertical, and Marine.

BOILER MATERIAL.

Destructive Forces.—From the time the steam boiler is constructed until it is finally destroyed there are numerous agents continually at work which tend to weaken it. These forces, or agents, attack the boiler both from the outside and from the inside, and in consequence the



life of all boilers is limited. Their attack is most insidious, and unless carefully watched will finally destroy the strength of the boiler even before it is suspected that they are at work. On the other hand there is nothing from which the boiler can draw sustenance to replace its losses. The atmosphere without and the water within the boiler, are both most destructive agents. The water itself which is evaporated within the boiler contains injurious minerals, which attack the metal from the time that the water is fed into the boiler until it is evaporated into steam. In addition to these injurious ingredients, there are also organic substances in the water, which likewise attack the metal. The fuels which are burned in the furnace, contain even more injurious forces which attack it from the outside of the shell. Among the most injurious of these forces found in fuel are the sulphurous and other acids contained in the fuel. These forces are not only at work when the boiler is in use, but also when it is not in use. It can therefore be seen how necessary it is that great care be taken of a boiler, and why it is that only competent engineers and firemen should be placed in charge of them.

This would not be so necessary if the only loss in the deterioration or destruction of a boiler was a financial loss, but when we consider the enormous force pent up in them, liable at any time to spread death and destruction around them should they be weakened beyond a point of safety, or, should an incompetent person be placed in charge, we then can understand why it is that the steam boiler is surrounded at all times with every precaution, and the public safety protected by the most rigid laws.

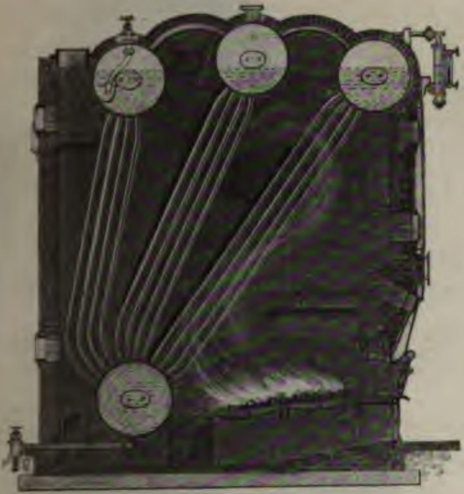
The material selected for the construction of boilers must not only be of great strength, but also must be elastic and durable.

Cast Iron was the material of which the earliest forms of boilers were made, but it has been entirely discarded in the construction of the modern high pressure boilers, and now only used in low pressure boilers for heating purposes where the steam pressure carried rarely exceeds 15 pounds to the square inch.

This is due to its low tensile strength and its unreliable nature. It possesses the advantage of cheapness and qualities to resist corrosion, and while it has been found unsuitable for boiler use it is still largely used in the construction of feed water heaters owing to its value in resisting corrosion. It is also used for boiler fittings where no great strength is required, and where they are not exposed to the heated gases from the furnace.

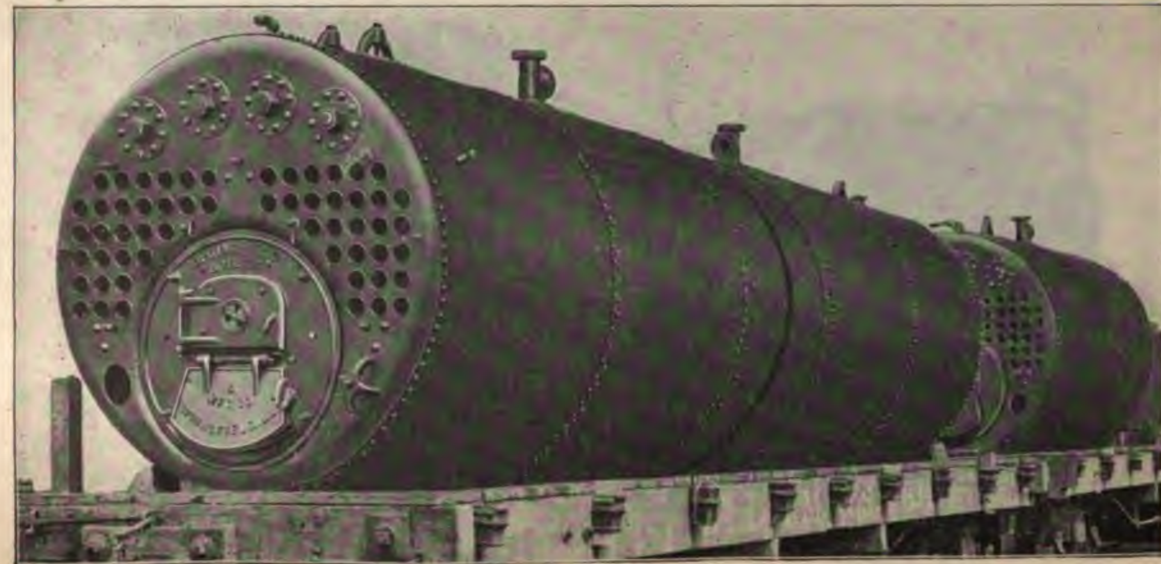
Wrought Iron was largely used up to about 1870, and possessed many advantages over any other metal for boiler use. It is strong, tough and fibrous, and combines high tensile strength with great ductility and freedom from brittleness.

Steel is now accepted as the best metal for all character of boilers, and it has entirely displaced both cast and wrought iron for boiler work. It has great tensile strength, ductility, toughness and freedom from unsoundness. Boiler steel is made by the open hearth process, and contains from .15% to .25% carbon. While a larger per cent of carbon increases the tensile strength of the metal, it **lessens** its ductility.



A Type of a Water Tube Boiler.
Fig. 15.

A Type of a Water Tube Boiler.
Fig. 16.



An Internal Furnace Boiler.
Fig. 17.

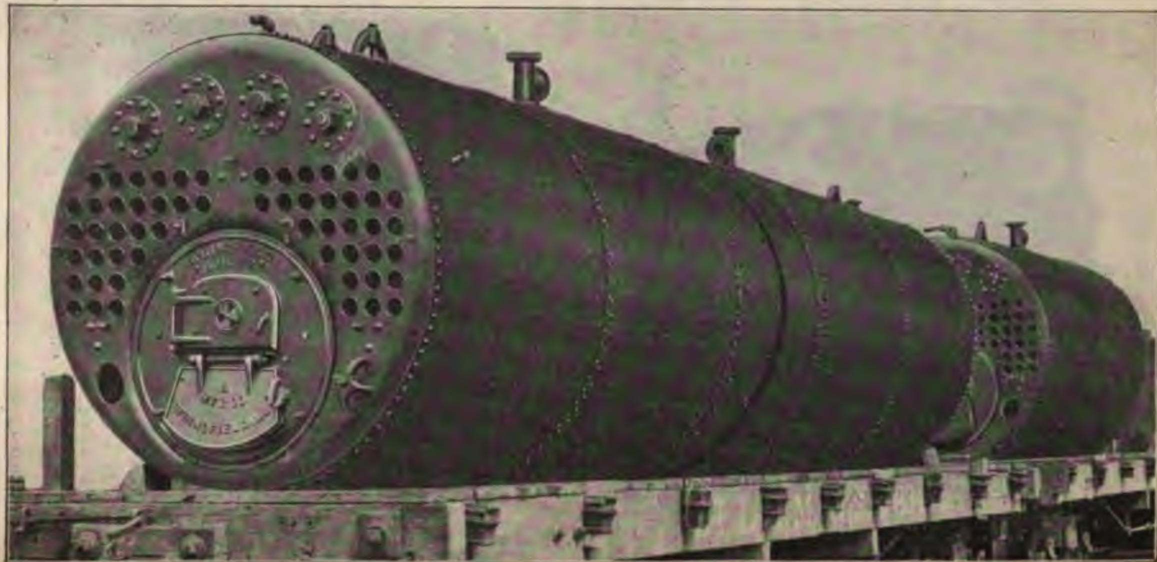
IRON AND STEEL.

It is most important that every one who works around or is in charge of a steam boiler, should know something about the different properties of iron and steel.

Ingredients.—Commercial iron and steel are metallic mixtures, the chief ingredient of which is the element "Iron," that is, pure iron, of which they contain from 93% to 99%. The difference between iron and steel is principally due to the composition and proportion of the remaining ingredients.

The **Iron Ore** from which both these metals are made contains from 35% to 65% of iron, the balance being oxygen, phosphorus, sulphur, silica, and other impurities. The ore is charged in a blast furnace, mixed with lime stone as a flux and melted down with either charcoal, coke, or anthracite coal as a fuel. The resulting metal obtained is what is commercially known as **Pig Iron,** containing about 93% of pure iron, 3% to 5% of carbon and a trace of silicon, phosphorus, sulphur, etc. This pig iron is used in foundries for the manufacture of iron castings, by simply remelting it in a cupola which does not materially change its chemical composition; the only results being a closer grain and somewhat increased strength.

In the manufacture of **Wrought Iron** the pig iron is melted in so-called puddling furnaces, by charging about one-half a ton in a furnace, and, while in the molten state, it is stirred up with long iron hooks by the puddler so as to expose every part of the iron bath to the action of the flame in order to burn out the carbon. This is readily done as carbon is nothing more than pure coal.



An Internal Furnace Boiler.
Fig. 17.

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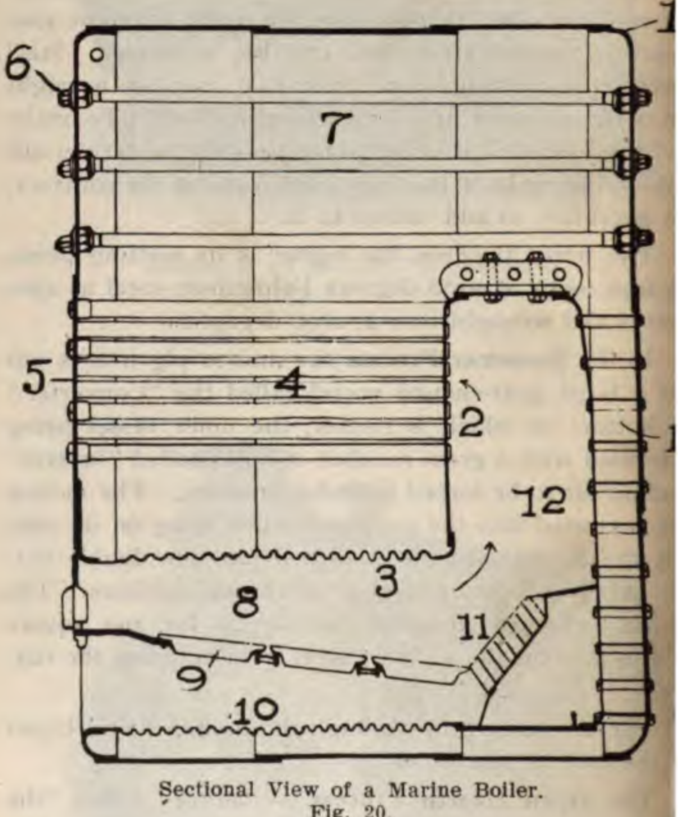


Sectional View of a Marine Boiler.
Fig. 20.

to a high temperature, over 1000 degrees Fahrenheit before entering the combustion chamber, by passing them through regenerative chambers. Owing to this heating of the gas and air a very high temperature can be maintained in the furnace. To the molten metal certain chemicals are added to keep it in a state of agitation, which takes the place of puddling or stirring it.

Cementation Process.—The oldest method of making crucible or tool steel is by the cementation process, in which the wrought iron bars are packed in air-tight retorts with powdered charcoal between the bars. The retorts so filled are then placed into a cementation furnace and kept red hot for several days, during which time the iron will **absorb** about one and one-half per cent of its weight of carbon.

Malleable Castings are produced in just the **reverse** way from the cementation process.

Instead of taking wrought iron and **adding** carbon to them, iron castings are packed in similar retorts with an oxide of iron, usually hermatite ore, and kept red hot for several days, permitting the oxygen of the ore to absorb the carbon in the iron, thus extracting the carbon.

Malleable castings are largely used for boiler fittings where cast iron is not permitted, although the latest requirements of good boiler practice, require **all** fittings to be of steel.

The material employed in the construction of boiler shells should possess two qualities that are absolutely essential to render them safe.

These qualities are **Tensile strength** and **ductility.**

Tensile Strength.—By tensile strength is meant the amount of force which, steadily and slowly applied in

a line with the axis of a metal, just overcomes the co hesion of the particles, and pulls it into separate parts

Ductility.—This is the property of a metal whicl permits it to be extended by a pulling or tensile force an remain extended after the force is removed. The greate the permanent extension, the more ductile the metal.

The tensile strength must be sufficient to withstan the stress due to the pressure of the steam, and the duc tility must be sufficient to prevent cracking by unequa expansion and contraction from frequent heating an cooling.

The one metal which possesses these two proper ties above all others, is **steel,** and it is therefore th metal universally adopted for the construction of al boiler shells, and for most of the fittings.

Requirements.—The manufacturers of boiler plat are required to stamp the tensile strength of the plat at the corners of each sheet or plate, about 4 inches fron its edge, and at or near the center of the plate; also th name of the manufacturer and the place where the plat is manufactured. Each plate has a coupon attached t be cut off and used for testing the material. Ever plate is numbered and recorded, and in this way a com plete oversight is kept of every plate used in the con struction of a boiler from the time the iron ore is melte to the final inspection of the boiler when completed an ready to be fired.

STANDARD SPECIFICATIONS FOR SPECIAI OPEN-HEARTH PLATE.

Adopted by the Assn. Am. Steel Manufacturers, Jul 17, 1896.

Steel shall be of four grades—**Extra Soft, Fire Bo Flange** or **Boiler,** and **Boiler Rivet Steel.**

Extra Soft Steel.—Ultimate strength, 45,000 to 55,000 pounds per square inch. Elastic limit, not less than half the ultimate strength. Elongation, 28 per cent. Cold and Quench bends, 180 degrees flat on itself, without fracture on outside of bent portion. Maximum phosphorus, .04 per cent; maximum sulphur, .04 per cent.

Fire Box Steel.—Ultimate strength, 52,000 to 62,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 26 per cent. Cold and Quench bends, 180 degrees flat on itself, without fracture on outside of bent portion. Maximum phosphorus, .04 per cent; maximum sulphur, .04 per cent.

Flange or Boiler Steel.—Ultimate strength, 52,000 to 62,000 pounds per square inch. Elastic limit, not less than one-half the ultimate strength. Elongation, 25 per cent. Cold and Quench bends, 180 degrees flat on itself, without fracture on outside of bent portion. Maximum phosphorus, .06 per cent; maximum sulphur, .04 per cent.

Every finished piece of steel shall be stamped with the melt number.

Rivets and Riveting.—In the construction of a boiler, the following is the usual order of operations in the shop: (1), the flat plates from the rolling mill are cut or sheared to the desired size; after being sheared they are placed in a machine that smooths the rough edges. Next the rivet holes are punched, or drilled, at the required distances near the edge of the plate. The plate is then passed through large rolls and bent to a cylindrical form in such a way that the corresponding rivet holes in the two edges come directly opposite each other. One or two bolts are put through these holes

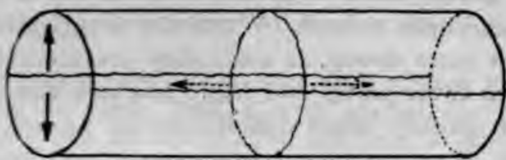
to hold the edges together, and the plate is then rivetec The heads are next flanged and riveted in place. Afte the riveting is completed, the tubes or flues are put i and expanded, the stays and braces are put in place, an the boiler is ready to be installed.

Riveting.—Rivets are used both in the longitudina and the girt, or circular, seams of the boiler; but it i the longitudinal seams which require the most strengt to hold them together, as the pressure upon the shell c the boiler is far greater than on the heads, there bein much more surface exposed to the pressure of the stean

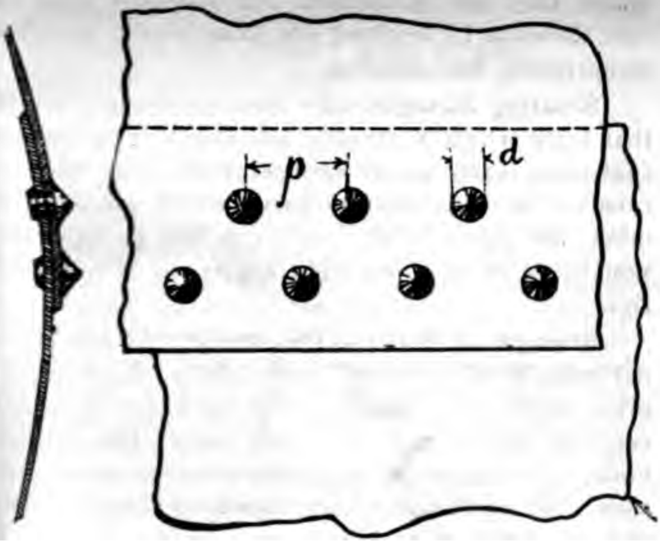
Internal Forces.—The cylindrical shell of a boil is subjected to two internal forces which tend to ruptu it, as is illustrated in Fig. 21. One force, indicated b the two arrows (1), act in the direction of the **lengt** which tends to tear the shell as shown by these arrow This stress must be borne by the **heads** of the shell, ar is therefore upon the circular or girt seams. The oth force, indicated by the arrows (2), acts perpendicular the axis of the first force, and tend to rupture the boil in a longitudinal plane, that is, **lengthwise** of the she This stress is borne by the **shell** of the boiler, and therefore upon the longitudinal seams or joints.

These two forces are opposed by the strength tenacity of the material of which the shell is compos

It can be shown by mathematicians that the magr tude of the force tending to rupture the shell in a long tudinal plane, that is, along the longitudinal seams joints, is equal to the internal diameter of the shell mu tiplied by the length multiplied by the pressure. It h been further proved that the circular or girth seam a boiler need only be single riveted, while the long



Stresses on Boiler Shells.
Fig. 21.



A Lap Joint.
Fig. 22.

tudinal seams must be double riveted, triple riveted, or even quadruple riveted. When the longitudinal seams are made extra strong, as when they are made butt joints with two cover plates and triple riveted, the girt seams are then usually made double riveted as an extra precaution.

Stresses.—Riveted joints may fail in several ways: First, by the rivets shearing. Second, by tearing the plate in a section between the rivets. Third, by the cracking of the plate between the rivet holes and the edge of the plate. Fourth, by crushing the plate or rivets where they are in contact. All stresses upon boilers may therefore be resolved into three kinds, viz.: Tensile, compressive, and shearing.

Shearing Strength.—By shearing strength is meant that force which, if steadily and slowly applied at right angles, or nearly so, to the line of the axis of the rivet, causes it to separate into parts, which slide over each other, the planes of the surface at the point of separation being at or about right angles to the axis of the rivet.

Strength of Boiler.—The strength of the longitudinal seam in all forms of boiler shells, determines to a great extent the pressure which the boiler is capable of carrying with safety. It is the object therefore of all boiler constructors to make this seam as strong as possible. To do this there are numerous forms of riveting and constructions of joints.

Rivets.—Rivets are usually made by forging from round iron bar or mild steel, with a cup, conical or pan-shaped head. The cylindrical part, called the shank, is a little smaller and has a slight taper. The conical head

vet is the form most generally used in boiler construction.

Formerly all joints of boilers were riveted by hand, but riveting is now done almost exclusively by machinery. If done by hand, a red hot rivet is inserted in the hole and the second head formed by two riveters using hammers.

The disadvantages of hand riveting was slowness and a tendency to form a shoulder before the rivet filled the hole. The shearing strength of steel rivets is about 45,000 lbs. per square inch, and of iron rivets about 40,000 lbs. per square inch.

DESIGNS OF JOINTS AND STAYS.

Riveted Joints.—There are various forms and strengths of riveted joints.

Lap Joints.—If one plate overlaps another, as shown in Fig. 22, it is known as a lap joint. If a single row of rivets is used it is called a single riveted lap joint. Such a joint has about 56 per cent of the strength of a solid plate. If another row of rivets is added, it is called a double riveted lap joint. Such a joint has about 70 per cent of the strength of the solid plate. If still another row of rivets is added, it is called a triple riveted lap joint. Such a joint has about 75 per cent of the strength of the solid plate. The riveting in these joints may be either what is known as chain riveted, i. e., where the rivets are in straight lines and immediately opposite each other, or, zig-zag riveted or staggered, as shown in the above cut.

In zig-zag or staggered riveting, the rivets of one row are opposite the spaces of another row.

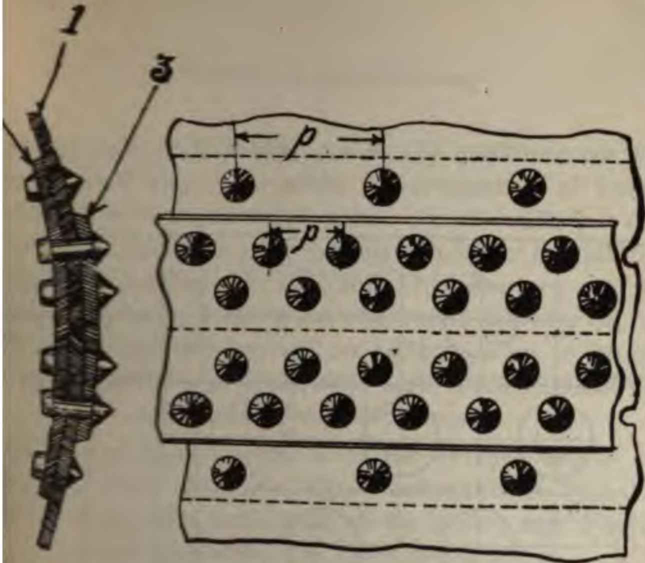
Pitch of Rivets.—In Fig. 23, the distance p represents the pitch of the rivets, by which is meant the distance between the **centers** of the rivets. The diameter of the rivet hole is indicated by the space d in Fig. *22*.

Butt Joints.—If the two plates are kept in the san plane and a cover or butt strap riveted over the joint, it then called a butt joint. If an inside butt strap is al added, it is called a double butt joint, as illustrated Fig. 23. A single butt joint is about equal in strengt to a lap joint having but one row of rivets, but a doub butt joint is much stronger. In Fig. 23 is shown a stan ard triple riveted butt joint with an efficiency of 88 p cent. See Fig. 23 on page 76.

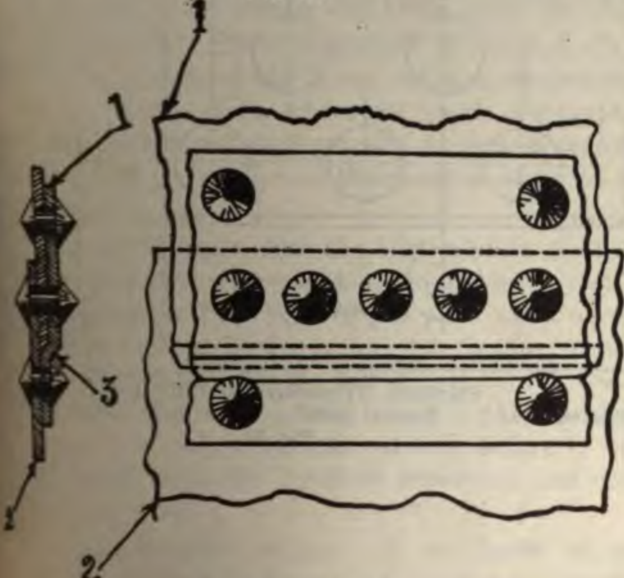
Locomotive Joints.—Fig. 24 illustrates the locom tive joint, a combination of the lap and butt joint, whi joint is used mostly for locomotive work, but has fou little favor for stationary work.

Lap joints are used for the circular or girth sean and the butt joints for the longitudinal seams. The l joint is rarely used for longitudinal seams, although un recently it was the most popular form of joint, even f high pressure boilers.

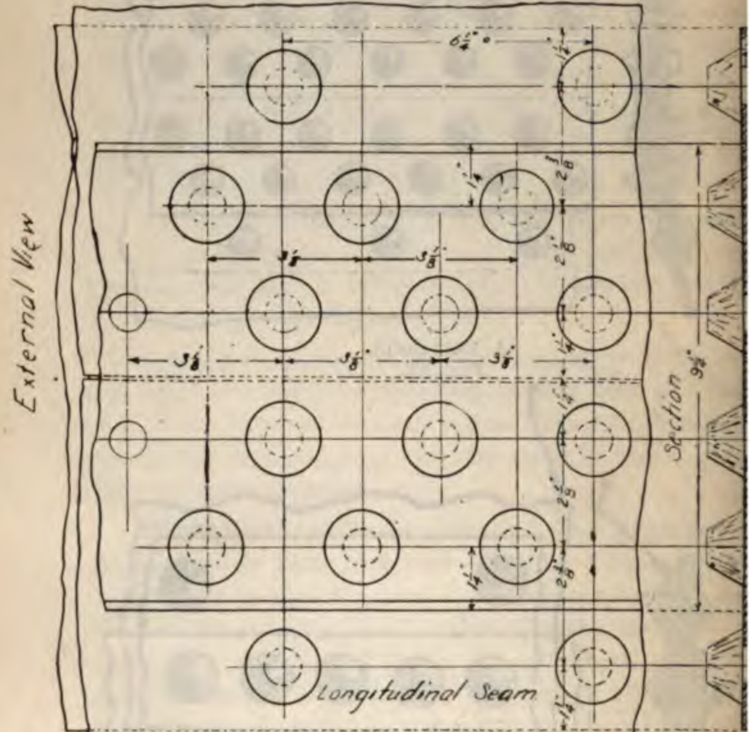
Regulations.—The lap joint is now regarded w such disfavor that both the cities of Chicago and Louis have within the past two years prohibited its u in the construction of all boilers to be used in the cities, they requiring the use of butt joints on all lon tudinal seams. The above cities require all boilers h ing cylindrical shells or drums of more than 42 inches diameter, and carrying more than 15 lbs. steam press to the square inch, to have all longitudinal seams but and held together by straps riveted over them. Wh single butt straps are used, they must not be less thickness than the shell plates, and where double b straps are used, each strap or cover must be not less t five-eighths of the thickness of the shell plate.



A Butt Joint.
Fig. 23.



A Locomotive Joint.
Fig. 24.



Standard Triple-Riveted Butt Joint.
Efficiency 88 %. Rivets 11-16". Holes ¾". Pitch 3⅛"—
Fig. 23.

The above regulation practically prohibits the further use of the lap joint in the construction of all boilers to be built for use in those cities. As about 80 per cent of all boilers now in use are made with a lap joint, it will make a most radical change, but one required for public safety, owing to the rapid increase in the amount of pressure carried on boilers. This is largely due to the growth of electricity, high speed engines, and increased demands of manufacturers.

The principal objection to the further use of the lap joint, is the impossibility to detect, either by an internal or external inspection of the boiler, any fracture or crack occurring along the inner or outer lap.

Since the crack, or fracture, does not extend through the metal a leak is not caused, and being under the edge of the lap it becomes almost impossible to detect it.

Again, the form of the boiler takes a distinct departure from a true circle where the seams are lapped, which is not considered good practice, in that, in forcing the edges together the fibre of the metal is likely to be injured.

This is not the case with the butt joint as the true circle of the sheets is maintained, without it being necessary to sledge over the edges of the plate as is necessary in the lap joint. If the boiler plate is very ductile it may never give any trouble, but if it is brittle it will be all the more liable to sustain injury in this mauling process, and it is only a question of time before it will yield and crack from the repeated expansion and contraction of the shell.

The crack usually develops on the inside of the joint, where it cannot be discovered even by the closest

form of inspection. While it is true that the interior a butt strapped joint is equally inaccessible to inspe tion, there is far less liability of such a crack developin

As a boiler is no stronger than its weakest point, an as the efficiency of the lap joint has been clearly show to be much less than that of the butt joint, and in vie of the fact that probably 70 per cent of all boiler explo sions occur from the use of the lap joint, it is only prope that its further use should be condemned.

In a 72-inch boiler with 90 lbs. pressure and rive pitched 2¼ inches, there would be a force of over 3 1 tons pulling on a strip 2¼ inches wide, being one riv in each row of a double lap joint. From this it can b seen how high must be the efficiency of the joint.

Safe Working Pressure of Boilers.—No rule to d termine the safe working pressure of a boiler can fi modern requirements which is not based upon the **effi ciency of the joint.** As the strength of all riveted join employed in steam boilers is less than that of the sol plate, its strength must be the chief factor in all calcul tions or rules for determining the safety of boilers.

The rule adopted by the most modern boiler make and inspectors, and the one which is undoubtedly t safest rule, is as follows, viz.:

Rule.—From the distance from center to center the rivets, subtract the diameter of rivet hole. Divi the remainder by the first number.

This result gives the percentage of the solid plate

Next, multiply the tensile strength of plate by i thickness in parts of an inch, and this product by t percentage of solid plate.

Divide this result by one-half the diameter of the boiler, and the quotient will be the bursting pressure per square inch.

Divide this by the factor of safety, and it will give the **maximum safe working pressure.**

Factor of Safety.—Owing to the great danger from steam boilers, every precaution must be taken for their safety, and a wide margin is therefore left between the bursting pressure of a boiler, and the actual working pressure which will be permitted on same. Defects in material and construction cannot always be detected, even with the most careful inspection, and this margin, or, the amount in which the bursting pressure exceeds the working pressure, is called the factor of safety, and is made sufficiently large to cover any possible defects.

When the material and construction is only moderately good the factor of safety should be made as high as 6, which means only one-sixth of the actual bursting pressure will be permitted on this boiler. If the material and construction are good and the boiler will probably be well cared for by competent men, the factor of safety is then placed at 4½ or 5. Most of the large cities of this country use a factor of 4, though St. Louis uses 4½ and Philadelphia a factor of 5.

Example of Application.—What is the bursting pressure, per square inch, on a boiler 54 inches diameter, plates 5/16 inch thick, tensile strength 50,000 pounds per square inch, pitch of rivets 3⅛ inches, diameter of rivet holes ¾ of an inch?

3⅛ equals 3.125
5/16 equals .3125
¾ equals .750

3.125) 2.37500(.76 equals percentage of joint.
2.1875

18750
18750

54 inches divided by 2 equals half diameter of boiler.

50.000 x .3125 equals 15625.000
15625.0000 x .76 equals 11875.000000

$\frac{11875.000000}{27}$ equals 439.81 pounds, or bursting pressure.

Factor of safety 4.5) 439.81

97.7 lbs. equals maximum work-pressure.

The rule adopted by the U. S. Government is not given here, as it does not meet modern requirements for stationary work; and, in fact, is antiquated even for marine work.

Staying.—If a boiler were spherical it would require no stays, but the flat ends or surfaces in all boilers must be stayed, otherwise the internal pressure would bulge them out and tend to force them into a spherical shape. The first and most important point in staying, is to have a sufficient number of stays so that they will entirely support such flat surfaces. The second requirement is to have them so arranged as to allow a free circulation of the water in the boiler. The third require-

[redacted]

ent, and naturally the most important, is to so arrange e stays as to permit a free and thorough inspection of e boiler.

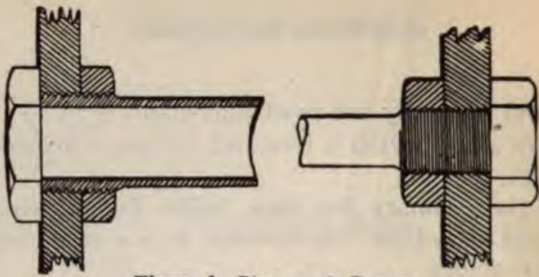
In the ordinary fire tube boiler the principal surces to be stayed are: the flat ends, crown sheets and comstion chamber.

One of the most common forms of stays is shown Fig. 25.

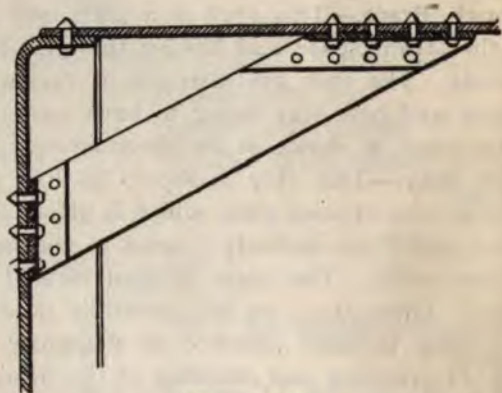
Through Brace.—This stay is a plain rod passing ough the steam space and having the ends fastened the heads. The ends are fastened in various ways, simplest and best way being to have nuts on both s of the plate, as shown in the above figure.

Gusset Stay.—This stay is shown in Fig. 26, and nsists of an iron or steel plate, which is placed between gle irons which are securely riveted to the head and ell of the boiler. The plate is then riveted to the gle irons. These stays are not generally used in this untry, owing to their absence of flexibility which ten induces grooving and cracking of the head plates.

Crow-Foot Stay.—The crow foot stay is the most mmon method used in this country for supporting the ds of stationary boilers. This stay is shown in Fig. , and consists of a round bar on one end of which is lded the crow foot, the other end of the bar being t as shown in the cut. The crow foot is riveted to e head, and the bent end to the shell. An improved m of crow foot brace is the McGregor brace, which sists of a single piece of sheet steel, bent in one heat. g weldless, it will bear a much greater strain than e welded crow foot brace. In the Huston crow foot ace, the crow foot is formed by flanging the plate of ch the brace is formed.



Through Stay and Brace.
Fig. 25.



A Gusset Stay.
Fig. 26.

A Crow-Foot Stay.
Fig. 27.

Diagonal Brace.—This brace, as shown in Fig. 28, consists of a plain rod connected to angle irons by means of split pins. This brace is not in general use.

Direct Stays.—For large boilers carrying high pressure, the most direct and strongest way of supporting the heads is to use through stay rods. Fig. 29 is sectional view of a boiler, showing stays and braces.

TUBES AND FLUES.

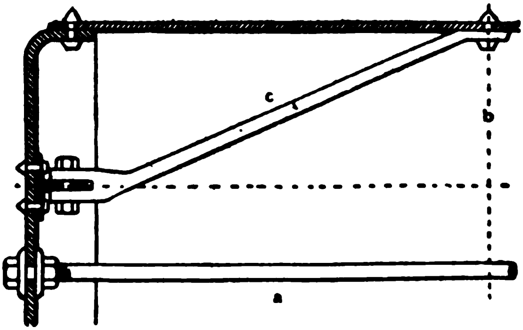
Use.—Tubes and flues are used for increasing the heating surface of boilers, though they also add strength to the boiler and assist in the quick raising of steam. The tubes when used for increasing the heating surface are made of charcoal iron or soft steel, and are either lap welded or solid drawn. When the tubes exceed 6 inches in external diameter they are called flues. While pipe is designated by its **internal** diameter, the size of tubes for boiler work is designated by their **external** diameter.

Dimensions.—Table No. 1 gives the standard dimensions of tubes in most common use in steam boilers.

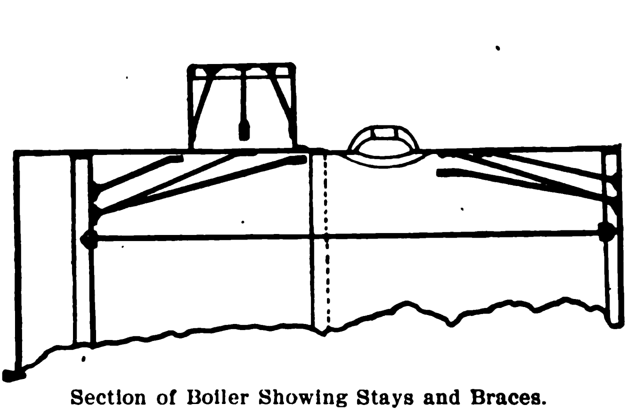
Number.—The number of tubes used in return tubular boilers vary with the size of the boiler and the conditions under which the boiler must work. The number of tubes usually put in return tubular boilers has been heretofore given.

Boiler tubes are usually **expanded** into the tube sheets, except stay tubes, which are screwed in and secured by lock nuts on both sides of the tube sheet. Fig. 30 illustrates how the tube ends are fastened in the tube sheets. The tubes are first expanded by means of a tube expander, and then beaded over so as to make them se-

[redacted]



A Diagonal Stay.
Fig. 28.



Section of Boiler Showing Stays and Braces.
Fig. 29.

cure. The manner of fastening the tube in the tube sheets varies greatly, but the method described above is the one most generally used.

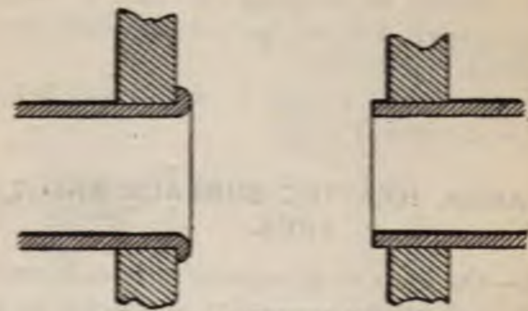
Flues are usually riveted to the flanged heads of boilers as is shown in Fig. 31.

GRATE AREA, HEATING SURFACE AND TUBE AREA.

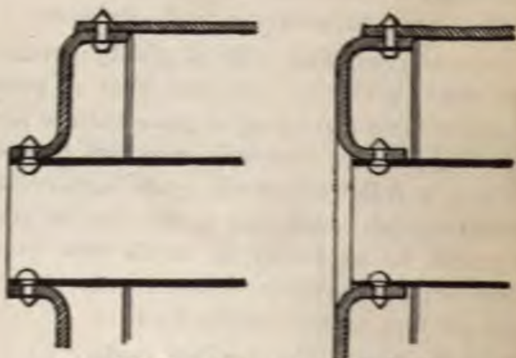
Basis.—The grate area, or grate surface, depends on the rate of combustion, the quantity of water to be evaporated per pound of fuel and the total weight of steam evaporated per hour. It can be seen from this how important it is that there should be sufficient grate area for the burning of fuel in a boiler furnace. To determine the necessary grate area to be placed under a boiler, it is only necessary to know the amount of steam the boiler will be called upon to generate to do its work.

For example, suppose that a plant requires 6000 pounds of steam per hour. Assume that 16 pounds of coal are burned per square foot of grate surface per hour, and that each pound of coal will evaporate 6 pounds of water. Then, it follows that the grate surface required would be 6000÷16x6 equals 62.5 square feet of grate surface. It would be necessary to divide this grate surface among several furnaces, since a grate longer and wider than six feet cannot readily be fired.

Heating Surface.—The heating surface of a boiler is that portion of the surface which is exposed to the action of the flames and hot gases. This includes only so much of the shell as is below the line of brick work which closes in the sides of the boiler. This line is called the **fire line** of the boiler, and is always deter-



Tubes as Secured to Head.
Fig. 30.



Flues as Secured to Head.
Fig. 31.

mined by the closing in of the side walls, as above this line the shell of the boiler cannot come in contact with the flames from the furnace or the heated gases. The exposed heads of the shell, and the **interior** surface of the tubes or flues constitute the remainder of the heating surface. The above applies only to shell boilers, the heating surface of a water tube boiler being somewhat different. In a water tube boiler the heating surface comprises that portion of the shell or steam drum below the brick work, the outer surface of the headers, and the outer surface of the tubes, as the interior surface of the tube is filled with the water to be evaporated.

To find the heating surface of a return tubular boiler the following rule must be used:

Rule.—Multiply two-thirds the circumference of the shell in inches by its length in inches; multiply the number of tubes by the length of the tube in inches and by its circumference; add to the sum of these products two-thirds of the area in square inches of the two heads or tube sheets; from this sum subtract twice the area of all the tubes and divide the remainder by 144; the result is the heating surface in square feet. Some rules call for only one head, but the better practice is to take both heads though the gases are much cooled when they reach the front head.

From this it can be seen that the greatest part of the heating surface of tubular boilers is furnished by the tubes, and not by the direct heat of the furnace against the shell as is generally supposed.

Ratio of Heating Surface to Grate Area.—In order to obtain the best results from a boiler, it is necessary that the temperature of the heated gases should pass into the chimney at as **low** a temperature as possible, as has been shown. A large amount of heating surface is therefore

LAP-WELDED CHARCOAL-IRON BOILER TUBES

TABLE OF STANDARD DIMENSIONS

Diameter		Thickness, Inches	Wire Gauge No.	Circumference		Transverse Areas			Length of Tube per Sq. Foot of		Nominal Weight per Foot. Pounds
External, Inches	Internal, Inches			External, Inches	Internal, Inches	External, Sq. Inches	Internal, Sq. Inches	Metal, Sq. Inches	Ex. Surf., Feet.	Int. Surf., Feet	
1	.856	.072	15	3.142	2.689	.785	.575	.21	3.819	4.462	.71
1¼	1.106	.072	15	3.927	3.475	1.227	961	.266	3.056	3.453	.89
1½	1.334	.083	14	4.712	4.191	1.767	1.398	.369	2.547	2.863	1.24
1¾	1.56	.095	13	5.498	4.901	2.405	1.911	.494	2.183	2.448	1.66
2	1.81	.095	13	6.283	5.686	3.142	2.573	.569	1.909	2.11	1.91
2¼	2.06	.095	13	7.069	6.472	3.976	3.333	643	1.698	1.854	2.16
2½	2.282	.109	12	7.854	7.169	4.909	4.09	819	1.528	1.674	2.75
2¾	2.532	.109	12	8.639	7.954	5.94	5.035	.905	1.389	1.509	3.04
3	2.782	.109	12	9.425	8.74	7.069	6.079	.99	1.273	1.373	3.33
3¼	3.01	.12	11	10.21	9.456	8.296	7.116	1.18	1.175	1.26	3.96
3½	3.26	.12	11	10.996	10.241	9.621	8.347	1.274	1.091	1.172	4.28
3¾	3.51	.12	11	11.781	11.027	11.045	9.676	1.369	1.018	1.088	4.6
4	3.732	.134	10	12.566	11.724	12.566	10.939	1.627	.955	1.024	5.47
4½	4.232	.134	10	14.137	13.295	15.904	14.066	1.838	.849	.902	6.17
5	4.704	.148	9	15.708	14.778	19.635	17.379	2.256	764	.812	7.58
6	5.67	.165	8	18.85	17.813	28.274	25.249	3.025	.687	.673	10.16
7	6.67	.165	8	21.991	20.954	38.485	34.942	3.543	.546	.573	11.9
8	7.67	.165	8	25.133	24.096	50.266	46.204	4.062	.477	.498	13.05
9	8.64	.18	7	28.274	27.143	63.617	58.629	4.988	.424	.442	16.76
10	9.594	.203	6	31.416	30.14	78.54	72.292	6.248	.382	.398	20.99

Table No. 1.

necessary to permit the hot gases time and opportunity to give up their heat to the water before passing up the chimney. The higher the rate of combustion, the greater should be the heating surface of the boiler.

In every day work this ratio between the heating surface and grate area varies between 45 and 50, which means that for every square foot of grate surface there should be from 45 to 50 square feet of heating surface for bituminous coal, and 36 square feet for anthracite coal.

For example, should the dimensions of a furnace be 6 feet by 6 feet or 36 square feet, then the heating surface of the boiler should be from 1600 to 1800 square feet.

Tube Area.—Since the products of combustion, or heated gases must pass through the tubes or flues, their combined cross sectional area, which is called the tube area, must be large enough to allow the entire column of heated gases to pass through them, with little friction and without interfering with the draft. But there must be sufficient friction to retard the flow of gases sufficiently to allow them to part with a greater part of their heat, and hence it can be seen that the tubes must be made neither too large or too small, but proportioned with the greatest care. For bituminous coal, the tube area should be from 1/6 to 1/7 the area of the grate surface, and for anthracite coal, from 1/8 to 1/9 the area of the grate surface.

DOME, STEAM AND MUD DRUM, MAN AND HAND-HOLE PLATES.

Use.—Domes are placed on cylindrical boilers for the purpose of increasing the steam space, and also for the purpose of drying the steam.

Domes are by no means necessary on stationary boilers, which is shown, by the constantly increasing number of boilers being built and successfully operated without them. They are, therefore, by no means a necessary attachment to a boiler, and it is only a question of time before their use will be entirely dispensed with by boiler makers. While they add some steam space, it is not enough to justify the extra cost of the dome, and also, the placing of a dome on a boiler weakens the shell to a considerable extent. The principal advantage claimed for the dome is that when the water level is carried too high, and the boiler is at the same time heavily fired, the danger of water entering the steam pipe is less than in a boiler without a dome. This is no real advantage, as a boiler properly constructed and operated may be forced far beyond its rated capacity and still furnish dry steam to the engine. As almost all boilers are sold with a guarantee of at least 25 per cent above their rated capacity, it can be seen what little real advantage is the placing of a dome on a boiler for this purpose.

Steam Drum.—Instead of a dome, a steam drum should be used. This drum consists simply of a cylindrical vessel connected to the shell of the boiler. When several boilers are set so as to form a battery, they are generally connected to one such drum, called the header, which is common to all the boilers. When each boiler has its own furnace, there should be a stop valve between each boiler and this drum or header, so as to permit the boiler to be cut out of service when not in use.

The strength and safety of these steam drums, or headers, should be determined by the rules governing the strength of boiler shells. They should also be as rigidly inspected as the boiler itself.

Mud Drum and Blow Off Apparatus.—The object of a mud drum is to collect the sediment which is precipitated from the water in the boiler. When used, it is placed underneath the boiler and near the rear end of same, being attached to the boiler by a suitable nozzle. It must be suspended in such a manner that no portion of the weight of the boiler comes upon it.

In boilers equipped with mud drums, the feed water is frequently introduced into the boiler through this drum, which has the advantage of permitting the feed water to be heated before entering the boiler, but the proper function of this drum is not to act as a feed water heater, but to collect the sediment in the water so that it can be more easily removed from the boiler through the blow-off pipe. In Fig. 8 is shown the location and dimensions of an ordinary steam drum attached to a horizontal boiler.

Blow Off Pipe.—The blow off pipe serves for the double purpose of emptying the boiler, and of discharging the sediment that collects. Each boiler must be provided with such a pipe that enters the boiler at its lowest point, or attached to the mud drum, when a boiler is provided with one.

This blow off pipe when exposed to the heated gases, must always be protected by a sleeve made of pipe, or by being bricked in, or protected by asbestos covering. The mud drum must also be protected from the heated gases by a brick wall built around it, leaving a small space between it and the wall.

Obsolete.—The use of a mud drum is fast becoming obsolete, and like the steam dome it will soon be entirely discarded.

Blow-Off.—The blow-off apparatus must be given most careful attention as the pipe is apt to clog with scale and sediment. The use of globe valves on the blow off pipe is therefore objectionable, as such valves do not open freely, and as a piece of scale or sediment may get between the valve and its seat. As a result, the water would leak out of the boiler unperceived. Modern practice requires plug-cocks packed with asbestos, which removes the objections above stated to the use of globe valves.

Surface Blowoff.—Boilers are sometimes fitted also with a surface blowoff, which is a pipe to which is attached a scoop shaped vessel placed three or four inches below the water level. The pipe is provided with a valve or cock. To operate same it is only necessary to open **wide** the valve or cock, which causes a rapid discharge through the pipe, the force of which draws the sediment into the scoop, and discharges it through same.

Man-Hole and Hand-Hole.—The man-hole is placed in the shell of a boiler to permit access to the interior of same for cleaning, repairing and inspecting it. They are usually placed either in the heads or in the top of all horizontal shell boilers, sometimes in both places. In water tube boilers, man-holes are usually placed in the upper drum, and either a man-hole or a hand-hole in the mud drum. The size of the standard man-hole is 11x15 inches, the longer diameter being placed at right angles to the axis of the shell.

Construction.—Hand-holes are constructed similarly to man-holes, the only difference being that they are made much smaller, permitting only the hand and arm to be inserted through them, and therefore, require only one yoke and one bolt to hold them in place.

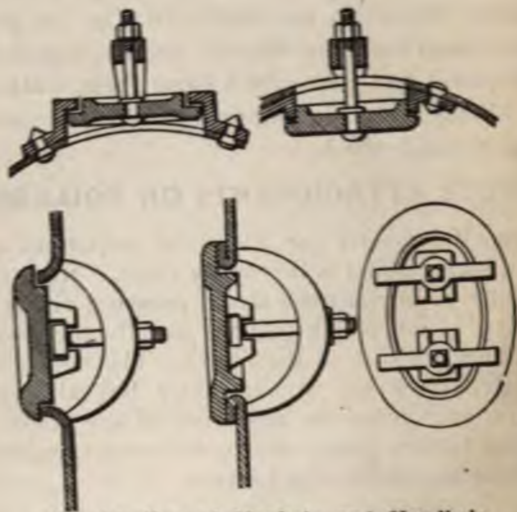
Both the man-hole and hand-hole should be sufficiently strong to sustain the stresses not only due to the direct steam pressure upon them, but also the stresses from the plate. In order to do this they are always reinforced, that is, a forged or reinforcing ring or rings is placed around the section that is cut out of the shell, and securely riveted to the shell. In Fig. 32, the construction of man and hand-holes is shown, together with the cover plates and yoke which close them. Man-holes and hand-holes are made elliptical to allow the cover to be passed through the hole.

SAFETY ATTACHMENTS ON BOILERS.

Safety Valve.—By far the most important attachment on a steam boiler is the safety valve. It is attached to the boiler to prevent the steam pressure rising above a designated point, which point is usually the maximum safe working pressure of the boiler. The necessity of a safety valve on every steam boiler has always been recognized, even from the incipiency of the boiler. One of the first boilers ever constructed was supplied with one of these necessary attachments.

When a boiler generates steam faster than the engine can use it, it is evident that a large quantity of steam must be continually forced into the confined steam space of same. This causes the steam pressure to continue to rise until an explosion takes place, unless some means of relief is afforded. It is the sole duty of the safety valve to prevent this increase of pressure above a dangerous point.

Construction.—Its construction is very simple, consisting of a plate or disk fitted over a hole in the boiler shell. This plate or disk is held in its place in one of three ways. (1) By a dead weight, (2) by a weight on



Construction of Manhole and Handhole.
Fig. 32.

a lever, (3) by a spring. The weight or spring is so adjusted that when the steam pressure reaches the designated point, the disk or plate is raised from its seat, permitting the surplus steam to escape through the opening in the shell.

Safety valves are designated from the way this plate or disk called the valve, is held in its place.

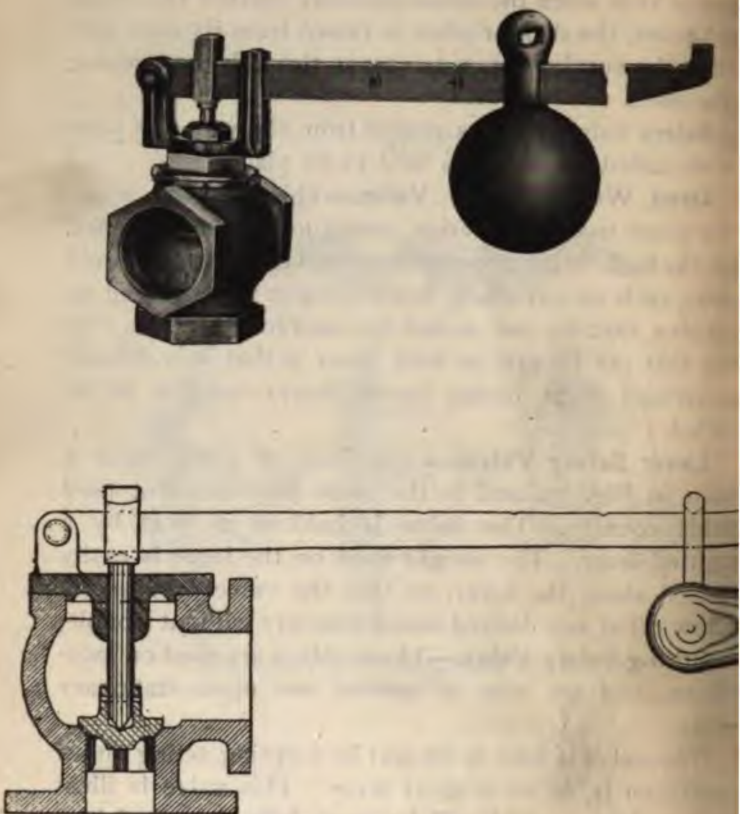
Dead Weight Safety Valve.—This form of safety valve is not used in America, owing to its inconvenience, since the high steam pressure now universally used would require such an extremely heavy weight to be placed on the valve that its use would be impractical. The only thing that can be said in their favor is that it is difficult to overload them, owing to the heavy weights to be handled.

Lever Safety Valves.—This form of safety valve is shown in Fig. 33, and is the most popular valve used in this country. The valve is held to its seat by a weighted lever. The weight used on the lever is easily adjusted along the lever, so that the valve may be set to blow off at any desired steam pressure without trouble.

Spring Safety Valve.—These valves are used on locomotives, and are also in general use upon stationary boilers.

The valve is held to its seat by a spring acting either directly on it, or on a short lever. This valve is illustrated in Fig. 34, and will be more fully described in a later chapter. Its advantage over the lever valve is its adaptability to any character of work, the use of the lever valve, on account of the lever and suspended weight, being confined exclusively to stationary work.

Area of Safety Valve.—The U. S. Government rule is the most generally used rule for finding the proper



The Lever Safety Valve, with Sectional View.
Fig. 33.

area of a safety valve, though there are several rules in general use which differ considerably in the results obtained.

The area of the valve must be sufficiently large to discharge the steam as fast as it can be generated by the boiler.

The U. S. Government rule is based upon the area of the grate surface, it being as follows, viz.:

For a **lever valve,** allow one square inch of area of valve for every two square feet of area of grate;

For a **spring loaded safety valve,** allow one square inch of area of valve for every three feet of arěa of grate.

This rule is **defective** in that it makes no difference in size of safety valve for **high** and **low** pressure boilers.

THE STEAM GAUGE.

The steam pressure in a boiler is measured in pounds per square inch. This pressure is the working steam pressure above the atmospheric pressure, which is about 14.7 pounds per square inch. Steam gauges are graduated to indicate the steam pressure **above** the pressure of the atmosphere, and should therefore stand at zero when the pressure is off the boiler; and should indicate the exact blowing off pressure when the boiler is in use and the safety valve is in action.

Working Pressure.—When we say that a boiler is working at 60 pounds pressure, we mean that the gauge pressure is 60 pounds to the square inch; that is, the pressure in the boiler is 60 pounds above the atmosphere pressure.

Absolute Pressure.—This is the pressure above vacuum, as is called a space entirely devoid of matter. Therefore, to find the absolute pressure on a boiler which has 60 pounds gauge pressure on same, the atmospheric

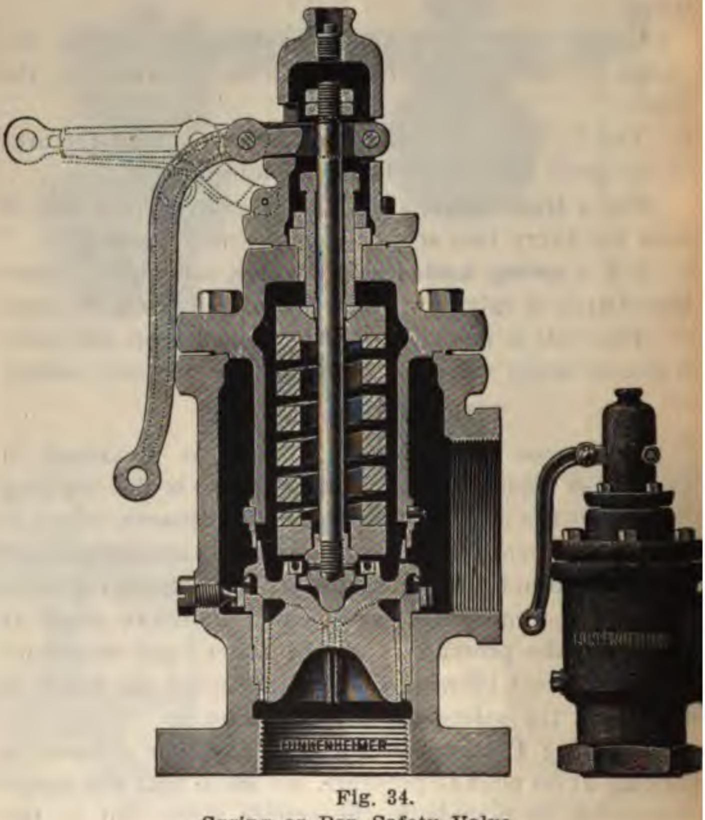


Fig. 34.
Spring or Pop Safety Valve.

[redacted]

'e must be added to the gauge pressure, which make the absolute pressure on this boiler about unds per square inch.

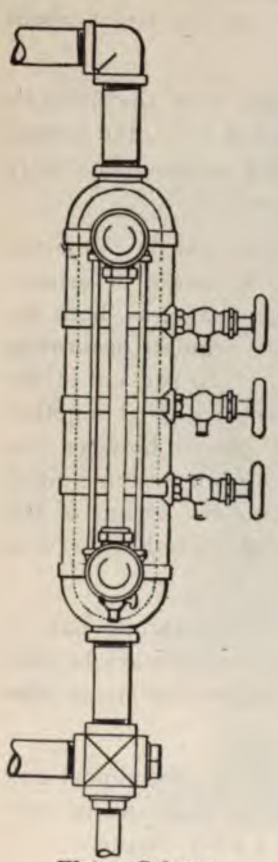
: atmospheric pressure varies with the altitude, vith the distance above the sea level, the atmos- ressure at sea level being 14.7 pounds per square

nection.—The steam gauge should be connected)iler in such a manner that it cannot be injured eat from same, or by rough usage, as, both for ıd economy, it should always regulate accurately n pressure within the boiler. To prevent injury t, a syphon, which is shown in Fig. 35 together ordinary steam gauge, is placed between the ıd the boiler. This syphon soon becomes filled densed steam which protects the spring of the from the injury the steam would otherwise

ery of boilers, each boiler should have a gauge. This gauge must always be con- tly to the boiler, and not to the steam pipe iler fittings.

team pressure gauge which is now almost uni- used was invented by M. Bourdon, and its con- will be fully described in a later chapter.

gauge operates on the principle that a flattened ıbe closed at one end, tends to become straight bjected to an internal pressure. The pressure :d in connection with the steam boiler, is the :hin the boiler.



Water Column.

Pressure Gauge.

Steam Gauge Syphon

Fig. 35.

GAUGE COCKS AND WATER COLUMN.

Gauge, or Try Cocks are attached to a boiler for the purpose of finding the **level** of the water. The cocks, or valves which are sometimes used, are usually three in number, and should be placed directly on the shell or head of a boiler, although they are often attached to a water column, which practice is entirely safe. A water column consists simply of a large pipe with its ends connected with the steam and water spaces of the boiler.

The lowest gauge cock is placed at the lowest level that the water may safely attain, and the uppermost cock at the highest level the water can be safely carried.

In Fig. 35 is shown a water column with the proper location of the gauge cocks.

Water Level.—To find the water level in the boiler open one of the cocks, and if steam issues the cock is then **above** the water level. Next, open the cock below this one, and if water issues it is **below** the water level, and hence the true water level must be between these two cocks.

Location.—In return tubular boilers, the lowest cock should be located about 3 inches above the upper row of tubes or flues. This insures that the tubes or flues will be covered with sufficient water at all times to prevent their burning. In water tube boilers, the lowest gauge cock should be attached about three inches above the fire line of the drum on same.

In all boilers having neither tubes nor flues, the location of the **fire line** determines the placing of the gauge cocks.

In the locomotive type of boilers, the lowest cock should be about 3 inches above the highest point of the crown sheet.

[redacted]

In a vertical boiler, the lowest cock is placed about two-thirds the distance of the shell from the fire box, this permitting about one-third of the shell for steam space.

The cocks on all types of boilers are usually placed about 3 inches apart.

In Fig. 36 is shown the Mississippi gauge cock, and the ball gauge cock, which are the two cocks most generally used.

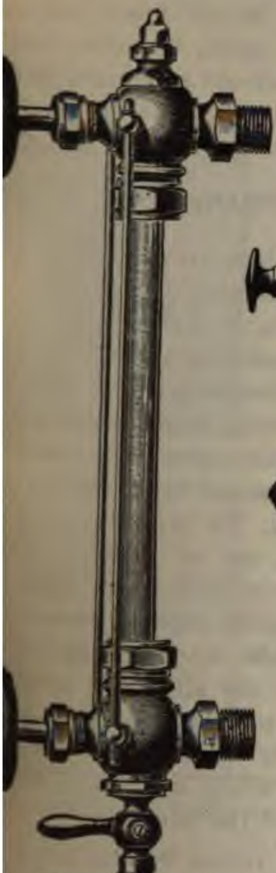
WATER OR GAUGE GLASS.

Connection.—A water glass is a glass tube with its lowest end in connection with the water space of a boiler, and its upper end connected with the steam space. Therefore, the level of the water in the gauge shows the level of the water in the boiler.

Fig. 36 shows the usual form of a water glass. The glass should be connected always directly to the head of the boiler, unless a water column is used, in which case. it is attached to it as shown in Fig. 35. It should be so located that the water will show in the middle of the glass when the water in the boiler is at its proper level.

A drip or drain cock is placed at the lower end of the glass for the purpose of draining and cleaning it.

Both gauge cocks and a water glass should be used on all boilers, so that one may be used as a check on the other. Gauge cocks are much more reliable than a water glass, as the glass not only often breaks, but it is apt to become choked with dirt and sediment from the boiler. This mud and sediment can be cleaned out by opening the drip or drain cock and allowing the steam and water to be discharged, which will blow out all such dirt and sediment.



Water Glass.

Mississippi Gauge Cock.

Ball Gauge Cock.

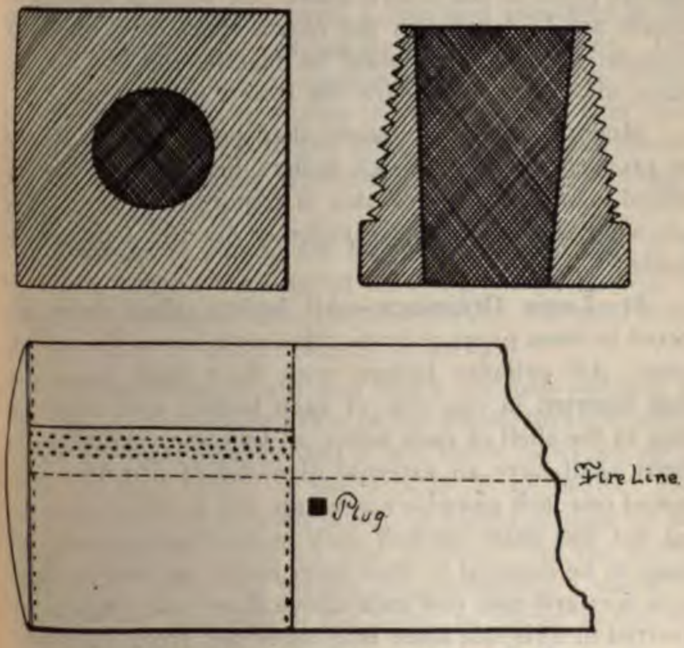
Fig. 36.

As both the safety of the boiler and the successfi operation of a plant depends largely upon maintainin the water level at its proper place, therefore both th gauge cocks and water glass should be constantly teste and blown out during the day, otherwise the true wat level may not be shown and disastrous results follow.

FUSIBLE PLUGS.

Use.—Fusible or safety plugs are required to be i serted in all boilers to give warning of low water Tl standard form of a fusible plug is shown in Fig. 37. consists of a brass shell threaded on the outside with standard pipe thread. The inside cavity is filled wi some alloy having a low melting point, which point determined by the ordinary steam pressure to be carrie by the boiler. This plug is inserted in the shell or dru of the boiler from the inside. In fire tube boilers, a additional plug is inserted in one of the tubes or flue As long as the plug is covered with water, the fusib metal is kept from melting by the coolness of the wate but should the water sink below the top of the plug, th heat of the steam will melt the alloy and permit th steam to be discharged, thus giving warning of lo water. The plugs are usually made with a conical fi ing in order to prevent the filling of alloy from bei blown out by the pressure of the boiler.

Location.—In horizontal return tubular boilers, t plug is usually placed in the second sheet from the fr just below the fire line, which would be about 3 inc above the upper row of tubes. One additional plug placed in the rear end of one of the tubes. In flue b ers, one plug is inserted in a flue at its highest po



Fusible Plug and Location in Shell of Boiler.
Fig. 37.

or in the shell or back head of boiler about three inches above the top of the flues.

In water tube boilers, it is inserted in the shell of the steam drum. In locomotive boilers, it is inserted in the highest point of the crown sheet. In vertical boilers, it should **not** be located in the crown sheet of same as is frequently done, but should be inserted in one of the tubes, about 2 inches below the lowest gauge cock.

Modern practice requires that safety plugs should be properly inserted in all boilers before they are installed. In many places this is required by law. The following is the ordinance enforced by the City of St. Louis:

St. Louis Ordinance.—All boilers shall have inserted in them plugs of brass filled with banca tin, as follows: All cylinder boilers with flues shall have one plug inserted in one flue of each boiler; and also one plug in the shell of each boiler, as follows: All plugs in shells shall have an external diameter of not less than that of one-inch gas pipe screw tap, and an internal opening not less than one-half inch in smallest opening, all plugs to be inserted in shell from inside, on second sheet from forward end, one inch above flues; all plugs to be inserted in flues not more than three feet from after end; all plugs to be inserted in flues to have an external diameter of that of a three-fourth gas pipe screw tap, and an internal opening of one-half inch, except flues or tubes of six inches or less, when plugs may be used with an external diameter of that of three-eighths gas pipe screw tap, with an internal opening of one-fourth of an inch. The Inspector of Boilers and Elevators shall have power to have one plug placed in each boiler not provided for

[redacted]

in this section, as he may deem necessary for the safety of lives and property, and it shall be the duty of the Inspector to see that such plugs are filled with banca tin at each inspection.

Care of Plugs.—These safety plugs should be removed at least once or twice a year and examined to see that the filling is not covered by scale or sediment. Unless this is done an incrustation is likely to form, covering the plug and preventing the heat of the steam from coming in contact with the filling or alloy, thus rendering the plug not only worthless, but a source of danger from its deception.

Convenient Piping for Fusible Plug.—In Fig. 38 is shown a convenient way of inserting a fusible plug in a boiler, it being not only very convenient, but sufficiently safe to pass the requirements of the law.

Construction.—Drill and tap a 1¼-inch opening in the top of the shell or drum of the boiler, through which insert a 1-inch pipe, so that it will reach to within about three or four inches of the bottom of the drum. This pipe should be extended about 14 inches outside of the boiler, using a nipple for this purpose. At the end of this nipple place the fusible plug, inserting a valve between it and the shell of the boiler, as shown in the cut.

So long as the end of the pipe in the boiler is covered by the water the plug will not melt, but upon the water getting sufficiently low to permit the steam to enter the pipe, it melts the plug and sounds an alarm. The valve can then be closed and a new plug inserted, without the necessity of shutting down the boiler, as would have been required had the plug been inserted in the usual way in the shell.

Composition and Melting Points of Fusible Pl

Tin.	Lead.	Melts Fahr.	Tin.	Lead.	Bismuth.	Mel
2	6	383	4	4	1	
2	7	388	3	3	1	
2	8	408	2	2	1	
6	1	381	1	1	1	
5	1	378	3	5	8	
2	2	372	1	1	2	
4	1	365	2	3	3	
3	1	340				
2	1	334				
1½	1	320				

Danger in Safety Devices.—No mention is here of high and low water alarms which are also safe vices, and the use of which is now generally advo While it is true that the above safety devices are a essential to the safe and economical operation of al ers, their use has its disadvantages and dangers, i it leads engineers and firemen to rely too much such devices, and not enough upon their own vig and knowledge.

HORSE POWER OF BOILERS.

Definition.—The term horse power when us connection with boilers, generally refers to the e ative power of the boiler, that is, the amount of that a boiler generates in a definite period of time ally in an hour.

Boiler Capacity.—The capacity of a boiler for ating steam depends upon the extent and dispositi the heating surfaces, the area of the grate, and the v of fuel consumed. The circulation of the water i

pound of water from and at 212 degrees Fahrenheit, therefore one horse power is equal to the evaporation of 33,305 divided by 966, which is equal to 34½ pounds of water evaporated from and at 212 degretes Fahrenheit. This then constitutes one horse power for boilers.

It is further found that the evaporation of 34½ pounds of water from and at 212 degrees Fahrenheit requires the same number of British Thermal Units, or heat, as the evaporation of 30 pounds of water at 100 degrees Fahrenheit into steam at 70 pounds gauge pressure.

From this calculation has been adopted the rule for determining the horse power of all boilers, viz.:

Rule.—One boiler horse power is equal to an evaporation per hour of 30 pounds of water from 100 degrees Fahrenheit to steam at 70 pounds pressure; or is equal to an evaporation of 34.5 pounds of water per hour from and at 212 degrees Fahrenheit.

Strictly speaking, there is no such thing as the horse power of a steam boiler, but the term has so long been used that an explanation of its meaning is necessary. When first used, it signified that the boiler would furnish steam to an engine of the same horse power. For instance, if a certain boiler furnished steam for a 20 horse power engine, the boiler for same would be called a 20 horse power boiler. If the same boiler furnished steam for a 60 horse power engine, it would be called a 60 horse power boiler.

Standard Rating.—It was therefore necessary in order to avoid confusion in the rating of boilers, to adopt a **standard** by which all boilers should be rated. To do this elaborate experiments and tests were made, and the

above rule was recommended as a standard by the judges in charge of boiler trials at the Philadelphia Centennial Exposition. Their recommendation has been genally accepted by American engineers, and whenever in this country the term boiler-horse-power is used in connection with stationary boilers, it is to be understood as having the meaning above defined.

In other countries than America, boilers are usually rated not in horse power, but by specifying the quantity of water that they are capable of evaporating from and at 212 degrees Fahrenheit. When the horse power of marine boilers is stated, it generally refers to the horse power developed by the engines which receive steam from the boilers.

Equivalent Evaporation.—In order to permit easy comparison of results of boiler trials, it is usual to reduce them all to a basis of equivalent evaporation from and at 212 degrees Fahrenheit. The method of doing this is to transform the evaporation, as determined under the actual feed temperature and steam pressure noted during the test, into an equivalent evaporation based upon a standard feed water temperature of 212 degrees F., and a steam pressure equal to normal atmospheric pressure at sea level, which is 14.7 pounds absolute.

In order to assist engineers, complete tables showing the factors of evaporation have been prepared. From these tables and the rules given, it becomes a simple matter of calculation to reduce the evaporation to a common basis. In Table No. 13 is given factors of evaporation for different steam pressures.

Heating Surface.—For ordinary practice boiler makers commonly rate the horse power of their boilers upon

the heating surface of same expressed in square feet. While the ratios between heating surface and horse power widely vary, the average is about as follows, viz.:

Type.	Sq. Ft. of Heating Surface.
Plain cylindrical	6 to 10
Flue	8 to 12
Multitubular	14 to 18
Vertical	15 to 20
Water tube	10 to 12

For example, tubular boilers are rated as having about 16 square feet of heating surface to the horse power. Then a 40 horse power boiler would have 40x16, equal 640 square feet of heating surface. Again, a similar boiler having 640 square feet of heating surface would be rated as a 40 horse power boiler.

To determine the horse power of a boiler necessary to develop a given horse power from an engine, it is only necessary to determine the amount of steam required by the engine to produce the required horse power. With a boiler capable of evaporating 2500 pounds of water from and at 212 degrees Fahrenheit per hour, an engine requiring 40 pounds of water per horse power hour, would develop 62½ horse power. With an engine requiring less than 40 pounds of steam per horse power, more than 62½ horse power would be obtained from this boiler.

This same boiler could therefore be used with a more economical engine requiring, say, 18 pounds of water per horse power hour, and it would then be called horse power boiler, although it is evident that the ty of the boiler itself has not been changed, but steam is used by the engine per horse power.

As will be seen later there is much difference between the boiler horse power, which is the horse power of a boiler, and the horse power of an engine; the first being an arbitrary unit, while the latter is definitely fixed.

Watt's Definition.—It has been necessary to change the definition of boiler horse power very much since when first adopted by Watt, it then being one cubic foot of water evaporated per hour from 212 degrees Fahrenheit for each horse power. This amount was at that period the requirement of the best engines in use. With the development and improvement of the boiler and engine, this standard has long become obsolete.

Boiler Efficiency.—The efficiency of a boiler is the ratio of the heat utilized in evaporating the water to the total heat supplied by the fuel. It can therefore be seen the efficiency of a boiler depends not alone upon the proper construction of the boiler, but also on the efficiency of the furnace as well. As it is not possible to determine the efficiency of the one without the other, the efficiency of a boiler is taken always to mean the combined efficiency of the boiler and furnace.

CHAPTER II.

QUESTIONS AND ANSWERS.

). What is steam?

.. Steam is an elastic and invisible gas, which re- to a liquid state as soon as it loses the heat by of which it was created. It is usually generated ating water contained in a closed vessel.

. What is evaporation?

. It is the process of changing water, or any other into vapor by means of heat.

. Can steam exist under pressure?

. Yes, it may exist under the same pressure as mosphere, or under a higher or lower pressure so as it is confined. When not confined, it at once es the temperature and pressure of the air and es vapor.

). In how many forms does all matter exist?

. In three forms, viz.: as a solid, liquid or aeri- . All matter has weight and occupies space. It offers more or less resistance when opposed by other es or forces.

Q. Is heat a body?

A. No, it does not possess any of the qualities of dy or substance. If a bar of cold iron is heated it not show the slightest increase of weight, although e quantity of heat has been absorbed by it. Heat ies no space as it will penetrate any body regard- of resistance. It cannot be confined, and it offers sistance to any body or force.

Q. Can heat penetrate a vacuum?

A. No, as a vacuum is a space entirely free of mat- it therefore cannot be penetrated by heat.

Q. What is meant by temperature?

A. Temperature is only a quality of heat describing its extent or degree.

Q. How is temperature measured?

A. Temperature is measured by instruments called thermometers.

Q. What are the principal thermometers?

A. Fahrenheit, Reaumur and Centigrade or Celsius, these being the names of the inventors.

Q. Describe the principal differences between these thermometers

A. The boiling point of water is placed at 212 degrees on the Fahrenheit; at 80 degrees on the Reaumur, and at 100 degrees on the Centigrade. The freezing point is 32 degrees on the Fahrenheit, and zero degrees on the Reaumur and Centigrade.

Q. How is heat measured?

A. Heat is measured by the amount of fuel consumed, or heat expended.

Q. What is the standard unit of heat

A. The standard unit of heat is the amount of heat necessary to raise the temperature of one pound of water at 32 degrees Fahrenheit one degree, i. e., from 32 to 33 degrees.

Q. What is the British thermal unit of heat?

A. It is that quantity of heat which is required to raise the temperature of one pound of pure water one degree Fahrenheit at or near 39.1 degrees Fahrenheit, that being the temperature of the maximum density of water. It is usually given as the quantity of heat required to raise the temperature of a pound of water from 62 degrees to 63 degrees Fahrenheit.

Q. How is this unit of heat usually designated.

A. By the capital letters B. T. U.

Q. What is the French thermal unit of heat.

A. The **Calorie** which is that quantity of heat re-ed to raise the temperature of one kilogramme of water one degree Centigrade at or about four de-es Centigrade, which is equivalent to 39.1 Fahrenheit.

Q. What is **specific** heat?

A. It is the amount of heat necessary to raise the temperature of a solid or liquid body a certain number of degrees. Water is adopted as the **unit** or standard of comparison.

Q. What has been adopted as the unit of comparison for determining the specific heat of a liquid or body?

A. Water. The heat necessary to raise the temperature of one pound of water one degree will raise, for instance, one pound of mercury 30 degrees, and hence the specific heat of mercury is said to be 0.033.

Q. What is **latent** heat?

A. It is the heat that is expended in changing a body from the solid to the liquid state, or from the liquid to the gaseous state without **changing** the temperature.

Q. What is **sensible** heat?

A. It is that portion of the heat applied to a substance that perceptibly raises its temperature, and it is therefore the heat which **affects** the thermometer.

Q. Does latent heat affect the thermometer

A. No. Water which starts its evaporation, say, at 85 degrees, carries as vapor in itself 85 units of sensible heat and 565 units of latent heat, as the sum of the sensible and latent heat in vapor of any kind of pressure must always be 650.

Q. Is the temperature of steam the same under different pressures?

A. No. Steam under different pressures has different temperatures, the **higher** the steam pressure the higher will be the temperature.

Q. What is the temperature of steam unde mospheric pressure?

A. About 212 degrees Fahrenheit.

Q. What is the temperature of steam ur ordinary boiler pressure of 100 pounds to the inch?

A. 327.6 degrees Fahrenheit, **absolute** pres about 337.8 degrees **gauge** pressure.

Q. What do you mean by **absolute** pressur

A. It is the pressure above vacuum in poi square inch.

Q. What do you mean by **gauge** pressure

A. It is the pressure above the atmosphe sure.

Q. What do you mean by **atmospheric pre**

A. It is the actual pressure of the atm which is 14.65 pounds per square inch at the s and this is called one atmospheric pressure or on phere. We usually speak of an atmospheric being equal to 15 pounds per square inch.

Q. What is **saturated** steam?

A. It is steam which carries in itself th amount of water and the proper temperature due to its pressure.

Q. What is the meaning of **superheated**

A. It is steam which carries in itself a **hig** perature than due alone to its pressure. It i contact with the **water.**

Q. What is the meaning of **surcharge** or w

A. It is steam which carries in itself **mo** than is due to its pressure.

Q. What is **condensed** steam?

A. It is steam which has lost its latent become water.

Q. What is **wire-drawn** steam?

A. It is steam which passes from a smaller opening into a larger one, which causes it to lose its power without giving any advantage.

Q. Why can so much **power** be generated from steam?

A. On account of the great elasticity of steam, which permits one cubic inch of water to be expanded into one cubic foot of steam, which is about 1700 times its original volume, and because of the amount of **heat** it contains.

Q. How is steam generated for power or heating purposes?

A. In a boiler.

Q. How would you classify steam boilers?

A. Into three classes, viz.: marine, stationary, and locomotive.

Q. How would you subdivide these classes?

A. Into six styles or types, viz.: marine, locomotive, vertical, flue, tubular and water tube boilers.

Q. What was the shape of the first practical boiler?

A. Spherical.

Q. By whom was it designed and when?

A. By Newcomen in about the year 1709.

Q. By whom was the "Wagon or Haystack" boiler designed?

A. By James Watt.

Q. How was the heating surface of this boiler increased?

A. By placing a flue in the boiler.

Q. What kind of draft was used in this boiler?

A. A wheel draft, since the gases pass entirely around the boiler. When a flue was used, it was then split draft.

Q. Was this an externally or internally fired boiler?

A. It was an externally fired boiler.

Q. What was the first **internally** fired boiler?

A. The Cornish boiler.

Q. What is the principal difference between ir ternally and externally fired tubular boilers?

A. In internally fired boilers the furnace is place **within** the shell, while in externally fired boilers the fu nace is placed **outside** the shell.

Q. What two improvements were made in th plain cylindrical boiler?

A. The heating surface was increased by the us of an internal flue, through which the hot gases passe to the chimney, and from which were developed **intern** flue boilers; the other, was the placing of the **furnace** ir **side** the shell of the boiler, and from which was deve oped the **internally** fired boiler.

Q. What is the principal difference between th Cornish and the Lancashire boiler?

A. The Cornish boiler has only one flue, which necessarily **large** and liable to collapse under extern pressure. On this account this boiler must be made f **small powers** only. The Lancashire boiler on the co trary has **two flues** and they can therefore be made muc **smaller** and **longer**, permitting much stronger flues to b used, and the boiler therefore to be used for **high pre sures** without danger of the flues collapsing.

Q. What are **Galloway tubes**, and what advanta is derived from their use?

A. They are water tubes used to **increase** the hea ing surface of the boiler; also to **strengthen** the intern flues and improve the **circulation** of flue boilers.

Q. What is the difference between a flue an multitubular boiler?

A. The chief difference is in the size and numb

It is an externally fired boiler in which the of combustion pass along the bottom of the the back of the boiler, and then through the tubes front where they enter the stack connection.

What advantages does a tubular boiler possess flue and cylinder boilers?

The tubular boiler takes up less room, gener- am more rapidly and requires less fuel. The eing of a smaller diameter and therefore of strength, are less dangerous than flues.

Is a tubular boiler as safe as a cylinder boiler?

Yes, as the tubes assist in bracing the heads.

Why are tubular boilers more economical than ylinder and flue boilers?

Because their heating surface is so much

What are the principal advantages of the water iler as compared with other types of boilers?

It is safer, more economical, steams more rap- more durable and is easier repaired. It may be taken apart and transported.

What are its only disadvantages?

the shell and **through** the tubes or flues; while in water tube boiler it passes **around** them. In fire boilers the **water** is **around** the tubes or flues, whil the water tube boiler, the **water** circulates **through** tubes.

Q. What are the chief materials used in boiler struction?

A. The materials mostly used in boiler const tion are wrought iron, cast iron and steel.

Q. What are the most important qualities requ in them?

A. Strength, ductility, elasticity and toughness

Q. How does the presence of phosphorus and phur in steel effect it?

A. Phosphorus above a certain amount makes s **cold short**, and sulphur above a certain amount make **hot short.**

Q. What do you mean by cold short and hot sh

A. A material is **cold short** when it cannot worked under the hammer, or by rolling, or be l when **cold** without cracking at the edges. A mate is **hot short** when it cannot be worked easily under hammer, or by rolling, at a red heat or any tempera higher than red heat, without fracturing or crack Such a material may be worked or bent when **less** t red heat.

Q. What is the minimum tensile strength allo in boiler steel?

A. As a rule not less than 60,000 pounds per squ inch.

Q. What bending test should boiler steel stand

A. A bend of 180 degrees flat on itself either or quenched.

Q. Of what are boiler tubes usually made?

[redacted]

A. Of charcoal iron or mild steel.

Q. What is meant by the efficiency of a joint?

A. The efficiency of a joint is the ratio between its trength and that of the solid plate.

Q. How is it expressed?

A. In per cent of the strength of the solid plate.

Q. On what does the efficiency of a joint depend?

A. On the diameter of the rivet hole, the pitch, the :ensile and shearing strength of the material, and the disposition of the rivets.

Q. How should a joint be designed?

A. So that its strength will equal as nearly as possible that of the solid plate.

Q. About what is the highest attainable efficiency in a triple riveted butt joint.

A. About 85 per cent.

Q. What is the minimum size of rivets that should be used in bracing the boiler?

A. Rivets smaller than ¾ inch should never be used.

Q. What character of heads are used without tays?

A. Heads that are either concave, bumped, or flat; eing such heads as used for plain cylindrical boilers, team drums, and mud drums.

Q. In a concave head, which side receives the steam essure?

A. The convex side.

Q. Which head is stronger, the concave or a imped head?

A. Bumped heads will sustain more pressure than ncaved heads.

Q. Is the strain greater on the heads or sides of a iler?

A. On the sides, because more surface is exposed to the steam pressure.

Q. How should boilers be strengthened?

A. With stays and braces.

Q. How do you find the absolute strain which is carried by the stays on the flat surface of a steam boiler?

A. Choose three stays at three corners of a square, multiply the sides in inches, and the result is the number of square inches of surface depending upon one bolt or stay for support.

Q. Give an example.

A. Suppose the stays measure 6 inches from center to center each way, with steam at 70 pounds pressure per square inch, then 6 x 6 equals 36, x 70 equals 2,520 pounds borne by one stay.

Q. What is a staybolt?

A. A staybolt is a screw bolt put through the outside and into an inside sheet, so as to prevent them from spreading or collapsing.

Q. Where are staybolts mostly used?

A. In locomotive type of boilers, in which boilers they are used to hold the fire box sheet and the outside shell so as to allow a water space between them.

Q. What is this water space usually called?

A. A water leg.

Q. How are stay bolts made and inserted?

A. They are made with one continuous thread and screwed through the outside shell and into the fire box sheet, and allowed to project through at each end about 3/16 inch so the ends can be up-set and made to act as a brace.

Q. What attachments to boilers are necessary for their safety?

A. The safety valve, steam gauge, gauge cocks, water glass and fusible plugs.

Q. What is the purpose of the safety valve?

A. The purpose of the safety valve is to prevent the steam pressure from rising above a certain point, which is usually the danger point.

Q. Is it safe to have a valve between the boiler and its safety valve?

A. No. No obstruction of any kind should be placed between a boiler and its safety valve.

Q. What is the purpose of the steam gauge?

A. To denote the amount of steam pressure in the boiler.

Q. How is the steam pressure gauge graduated to read?

A. It is graduated to read, or designate, the pounds pressure per square inch above the pressure of the atmosphere per square inch.

Q. What is the shape of the tube in the Bourdon pressure gauge?

A. The tube is elliptical so that when the fluid is forced into it under pressure it will tend to become straight, thus moving the pointer to which it is attached.

Q. What precaution should be taken in connecting a gauge to a boiler?

A. The connecting pipe between the gauge and the shell of the boiler should be so bent as to protect the spring from excessive heat. This bent tube is called a siphon.

Q. Where should the lowest gauge cock in a return tubular be placed?

A. The lowest cock should be placed about three inches above the upper row of tubes.

Q. What is the most important valve on a boiler?

A. The safety valve.

Q. What requirement is necessary in a safety valve?

A. That the area of the valve be large enough to discharge steam as fast as the boiler can generate it.

Q. What is meant by the horse power of a boiler?

A. It was first used to signify that the boiler would furnish steam to an engine of the same horse power, but it is no longer used in that sense. It is now an arbitrary unit, based on a standard unit of evaporation.

Q. What is the **standard unit** of boiler horse power?

A. It is the evaporation of 30 pounds of water from a temperature of 100 degrees Fahrenheit into steam at 70 pounds pressure, which is considered equivalent to the evaporation of 34½ pounds of water from and at 212 degrees Fahrenheit.

Q. To how many British thermal units is a horse power equal?

A. To 33.305 British thermal units.

Q. What rule is generally adopted by boiler makers to find the horse power of a boiler?

A. They find the number of square feet of heating surface, and divide it by 15 square feet.

Q. Why do they divide by 15 square feet?

A. It is the **average** allowance for one horse-power of a boiler.

Q. Is this an accurate way of rating boilers?

A. No. Since the heating surface is only one of the factors entering into the quantity of steam generated per hour.

Q. How much coal per horse power per hour should be consumed by a good water tube boiler with a high speed non-condensing engine?

A. In the back tube sheet, just above the top row of tubes.

Q. Where should the fusible plug be placed in the locomotive type of boiler?

A. In the crown sheet.

Q. Where should the fusible plug be placed in the return tubular boiler?

A. One plug should be inserted in the shell of the boiler from the inside one inch above the flues. A second plug should also be inserted in one of the flues or tubes not more than three feet from the after end.

Q. What is the size of the ordinary fusible plugs used in boilers?

A. All fusible plugs inserted in the shell or drum of a boiler should have an external diameter of not less than one inch gas pipe screw tap, and an internal opening not less than ½ inch in smallest opening. All plugs to be inserted in flues or tubes should have an external diameter of not less than ¾ inch gas pipe screw tap, and an internal opening of ½ inch, except flues or tubes of 6 inches or less, when plugs should be used with an external diameter of not less than ⅜ inch gas pipe screw tap, with an internal opening ¼ inch.

Q. Which gives up more heat to water, a horizontal or a vertical tube?

A. A horizontal tube.

Q. Why is it the finer the fuel used, the higher must be the chimney?

A. Because the fine fuel requires a stronger draft to burn it, and the higher the chimney the stronger the draft.

Q. What is the purpose of reinforcing rings?

A. They are used to strengthen the plate where it has been weakened by cutting a hole in it.

CHAPTER III.

COMBUSTION.

General Principles of Combustion.—Combustion is the action or operation of burning.

Since the fuel under the boiler, chiefly in the form of coal, is the source of all the energy transmitted to the steam engine, a study of the principles of combustion is necessary to understand how to utilize as far as possible this power. Heat lost by imperfect combustion cannot be recovered by any mechanical means, and its loss means a needless waste of money. Even with the most improved boilers and most careful attention, this heat loss is enormous. All fuels contain a definite number of heat units, which can be easily ascertained and which are definitely known.

In a pound of coal containing 13,500 of such heat units, the total loss amounts to as much as 12,227 units under conditions of ordinary work. This leaves only 1,273 units actually converted into power, the remaining units having been lost between the furnace of the boiler and the belt on the engine.

Furthermore, it can be seen how necessary is perfect combustion not only from the serious problem which confronts the steam engineer in the economical operation of his plant, but in the burning of soft coal without the formation of black smoke. This latter problem depends for its solution much more on intelligent work in the boiler room, which work requires a knowledge of economical combustion, than on patented furnaces and smoke consumers.

Coal.—All coal is composed largely of various compounds of carbon and hydrogen called **hydrocarbons.** When the coal is heated, these compounds are driven off partly in the form of gases, and partly as vapors. The substances driven off from the coal by heat are called volatile substances, while the portion remaining forms **coke,** which is composed chiefly of carbon. The process of separating the gases and vapors from the part of the coal that cannot be vaporized by the mere action of heat, is called **distillation.**

Coal is composed of carbon, hydrogen, nitrogen, sulphur, oxygen and ash. These elements exist in all coals but in varying quantities, depending upon the character and quality of the coal.

In the best grades of bituminous coal these elements constitute about the following per cent, viz.: Carbon 81 per cent; Hydrogen, 5¼ per cent; Nitrogen, 1 per cent; Sulphur, 1½ per cent; Oxygen, 6½ per cent, and Ash, 4¾ per cent, making a total of 100 per cent.

Coal is classified according to the per cent these different elements are contained in it, and all coal can be arranged in five classes, viz.:

First, Anthracite, consisting almost entirely of free carbon.

Second, Dry Bituminous coal, having from 70 to 80 per cent of carbon.

Third, Bituminous, caking coal, having from 50 to 60 per cent of carbon.

Fourth, Cannel coal, having from 70 to 85 per cent of carbon.

Fifth, Lignite, or brown coal, containing from 56 to 76 per cent of carbon.

Approximate Heating Value of General Grades of Coal.

	Per-Cent of-Combustible.		Heating Value Per Pound of
Kind of Coal.	Fixed Carbon.	Matter.	Combustible.
Anthracite	97.0 to 92.5	3.0 to 7.5	14,600 to 14,800
Semi-anthracite	92.5 to 87.5	7.5 to 12.5	14,700 to 15,500
" bituminous	87.5 to 75	12.5 to 25	15,500 to 16,000
Bituminous—			
Eastern	75 to 60	25 to 40	14,800 to 15,200
Western	65 to 50	35 to 50	13,500 to 14,800
Lignite	Under 50	Over 50	11,000 to 13,500

Wood.—Next in importance to coal as a fuel, wood is most generally used. Wood as a combustible, can be divided into two classes:

First, hard wood, such as oak, ash, beech and elm.

Second, soft wood, such as pine, birch and poplar.

Wood contains a great deal of moisture, and even several years after having been cut and kept in a dry place, it retains from 15 to 20 per cent of this moisture.

The steam producing power of wood has been found to be but little over half that of coal, owing to the great amount of water retained in it.

Peat.—This is the organic matter of vegetable soil of boggs, swamps and marshes. In its natural condition it contains from 75 to 80 per cent of water, and is therefore of but little value for steam producing power.

Petroleum—The use of crude oil as a fuel is increasing very rapidly, owing to the increased production reducing the price. Petroleum possesses many advantages as a fuel, among which are the ease of controlling the fire, and the absence of smoke due to the uniformity of combustion.

APPROXIMATE WEIGHT OF ONE CORD OF DIFFERENT KINDS OF KILN-DRIED WOODS, AND THEIR EVAPORATIVE POWER COMPARED WITH COAL OF AVERAGE QUALITY.

KIND OF WOOD	Approximate Weight of One Cord of the Wood	Weight of Coal that One Cord of Wood is Approximately Equivalent to in Evaporative-Power
English oak	3,850 lbs.	1,560 lbs.
Ash, beech and thorn, each	3,520 "	1,420 "
Red oak, hard maple and walnut, each	3,310 "	1,340 "
Apple-tree, pear-tree, cherry-tree and plum-tree, each	3,140 "	1,260 "
Birch, elm, plane-tree and hazel, each	2,880 "	1,190 "
Chestnut, brushwood and yellow pine, each	2,520 "	1,130 "
Pitch pine, alder, aspen and poplar, each	2,130 "	1,050 "
Willow, white pine or deal, each	1,920 "	970 "
Hemlock	1,220 "	580 "

Table No. 2.

About 126 gallons of the crude oil is equal to one short ton of good steam coal.

In Table No. 2 is given the approximate weight of one cord of different kinds of kiln-dried woods, and their evaporative power compared with coal of average quality.

In Table No. 3 is given the comparative cost of **oil** and **coal**, together with the equivalent price of oil per barrel.

Natural Gas.—The use of natural gas as a fuel is also rapidly increasing, due to the many new wells being found in different portions of the country.

On an average, 30,000 cubic feet of this gas is the equivalent of one ton of good steam coal. Practically one pound of gas is equal to two pounds of coal.

If one ton of coal costs $2.00, then natural gas must be worth from seven and one-half to ten cents per 1,000 cubic feet to permit of its economical use.

It is with coal as a steam producing power that we are mostly interested. In order to obtain the proper combustion of any fuel, a certain amount of air is necessary to be introduced into the furnace.

Draft.—There are several methods of producing the air required by a furnace for the combustion of the fuel, the two principal ways of producing a **draft** as it is called, being, viz.:

First, by means of a chimney, which is a natural draft.

Second, by means of a fan, blower or jet, which is called an artificial or mechanical draft.

Natural Draft.—Such a draft is produced by the **difference** between the weight of a column of hot gases contained within a chimney, and the weight of the same bulk of cold air on the outside of the chimney. It is well

...tion after allowing for steam consumed to produce the forced draft necessary for burning the fuel. 3. By "wet coal" is meant coal containing 3% of water	Bitumin... Mined W... and Used... and Sou... St...	Culm	No. 3, Buck... or Barl...	No 2, Buck... or Bi...	No. 1, Buck... and P...	Pittsburg... Used in... Pennsylv... on Gra...	Hand Fire...	Mechanical Stokers and Pat. Furnaces Introducing Air Over Fire — Ash 10%	Ash 5%
1	2	3	4	5	6	7	8	9	10
1. Pounds evaporation per lb. of wet, coal from and at 212 degrees, at about 10 square feet of heating surface per boiler horse-power . . .	7.5	7.75$_2$	8.25$_2$	8.50$_2$	8.75	9.50	10.00	10.50	11.00
2. Pounds evaporation per lb. of Beaumont oil from and at 212 deg., at about 10 square feet of heating surface per boiler horse-power	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8
3. Ratio of evaporation of oil to coal = line 2 ÷ line 1 = R .	1.97	1.91	1.79	1.74	1.69	1.56	1.48	1.41	1.35
4. Number of barrels of oil equivalent to a 2240 pound ton of wet coal = 2240 ÷ (322R) = N	3.54	3.64	3.90	4.00	4.12	4.46	4.70	4.94	5.15

EQUIVALENT PRICE OF OIL PER BARREL OF 42 U. S. GALLONS = Pc ÷ N = Po

Price of Coal per Ton of 2240 Pounds, Pc.									
5 $1.00 . .	$0.29	$0.28	$0.26	$0.25	$0.25	$0.23	$0.21	$0.20	$0.19
6 1.50 . .	0.43	0.41	0.39	0.38	0.36	0.34	0.32	0.30	0.29
7 2.00 . .	0.56	0.55	0.51	0.50	0.49	0.45	0.43	0.40	0.39
8 2.50 . .	0.71	0.69	0.64	0.62	0.60	0.56	0.53	0.50	0.49
9 3.00 . .	0.85	0.82	0.77	0.75	0.73	0.67	0.64	0.60	0.58
10 3.50 . .	0.99	0.96	0.90	0.87	0.85	0.78	0.75	0.71	0.68
11 4.00 . .	1.13	1.10	1.02	1.00	0.97	0.90	0.85	0.81	0.77
12 4.50 . .	1.28	1.23	1.16	1.13	1.09	1.01	0.96	0.91	0.87

Table No. 3.

known that any gas when heated is lighter than when cool. Now, when the hot gases pass into the chimney they have a temperature of at least 400 degrees and sometimes much higher, while the air outside the chimney has a temperature from 40 degrees to 100 degrees, depending upon the weather. Roughly speaking the air outside the chimney weighs twice as much, bulk for bulk, as the hot gases within the chimney. Therefore the pressure in the chimney is less than the pressure on the outside of the chimney, and the heavier air will flow to the place of lower pressure, that is, into the chimney through the furnace, it being the only inlet to same, thus producing a draft.

Artificial or Mechanical Draft.—This character of draft is produced by means of fan blowers or steam jets. According to the manner in which it is applied, this draft is known as a forced draft or an induced draft. Combustion is greatly increased by forcing or drawing more air into the furnace by these means.

Advantages.—The principal advantages claimed for mechanical draft are as follows:

(1) The ability to control the rate of combustion.

(2) A close regulation of the air required for combustion, thus avoiding improper combustion.

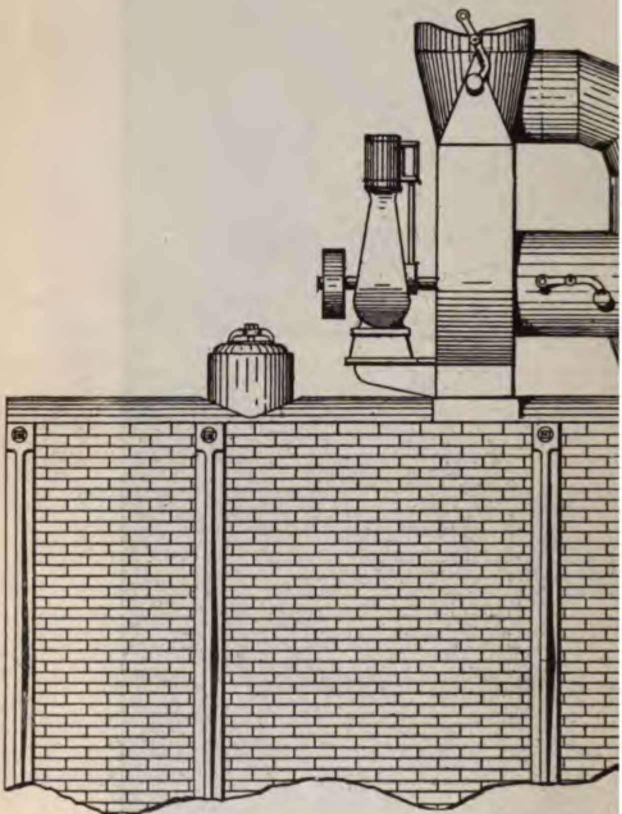
(3) Reduction of the first cost for producing the draft required.

(4) Permits the installation of regenerators and economizers without the necessity of providing additional means for maintaining the draft.

(5) Permits an absolutely uniform draft, regardless of atmospheric conditions.

(6) For increasing the draft where insufficient chimney capacity exists.

Forced Draft System.
Fig. 39.



Induced Draft.
Fig. 40.

(7) Permits the use of highly-heated air for combustion without increasing the waste heat.

(8) With mechanical draft the draft is independent of the condition of the fire, and consequently a banked fire can be started up quickly. With a natural draft, the intensity of the draft depends on the intensity of the fire, and is therefore least when the fire is low and draft is most needed.

With a mechanical draft the temperature of the furnace is always under control, and without waste of heat. Such a draft is both **positive** and **flexible**, and with it can be obtained and maintained almost perfect combustion, which means that all useful heat is utilized, and the complete absence of all smoke and smell.

With the forced draft system the air is forced through the fires from the closed ash pit, while with an induced draft, it is **drawn** through the fires by creating a vacuum over the fires. In the induced system the exhaust fan is used in place of the chimney, or supplementary to it, the products of combustion being drawn into the fan and exhausted into the chimney, which needs to be merely high enough to carry the smoke and gases clear of the roof of the building. The fan itself maintains the partial vacuum that would exist with a chimney of suitable height. Figs. 39 and 40 show these two systems in operation.

With the induced draft system the maximum intensity of the draft obtainable is greater and permits a much wider range regulation than with the forced-draft system. The leakage of air is also inward, thus avoiding the constant outward leakage, as in the forced-draft system.

The induced-draft system offers the additional advantage that the supply of air above the fire can be nicely

adjusted to secure more perfect combustion. While the maximum intensity of the draft of the chimney is largely dependent upon atmospheric conditions, as well as height, the intensity of the draft when produced mechanically is limited only by the speed of the fan, which can be made to cover a wide range of conditions.

When a forced draft alone is used with a chimney, the forced draft and the chimney pull should be so regulated that a **perfect balance** of the gases is maintained. When such a condition exists no cold air can be drawn into the furnace, even when the fire doors are left open.

Perfect Combustion.—In order to produce combustion, the carbon and hydrogen in the coal must combine with the oxygen in the **air**, and when we get the **proper** combination of these elements the result is **perfect combustion.** A high furnace efficiency demands a proper amount of air be supplied to the furnace per pounds of fuel burned. If **too little** air is supplied, it results in loss due to the incomplete combustion of the fuel, part of the carbon being burned only to carbon monoxide CO instead of to carbonic oxide CO_2, as it should be if the combustion is complete. On the contrary, **too much** air lowers the temperature of the furnace gases and thereby decreases the heat transferred per unit of heating surface, owing to the slight difference between the heated gases of the furnace and the temperature of the water inside the boiler. Too much air also **accelerates** the flow of gases through the tubes and flues of the boiler, thus giving less time for their heat to be absorbed. It is therefore necessary that only the amount of air required to burn the coal be admitted to the furnace. The amount varies, but it is generally found that from 12 to 24 pounds of air is needed to burn one pound of coal.

In order that one may clearly see why this amount of air is necessary for the proper combustion of coal, it is known that the air is composed of 21 parts of oxygen and 79 parts of nitrogen by volume, or 23 parts of oxygen and 77 parts of nitrogen by weight; and when we remember that the air that supplies a boiler furnace, or any other furnace, is supplied by **volume**, or according to the **space** vacated by the products of combustion, we see that it is necessary to take in a great deal of **air** containing an element that we do not need, in order to get the **oxygen** which is necessary for combustion.

Draft Water Gauge.—The intensity of the draft is measured by means of a water gauge, as shown in Fig. 41. The gauge consists of a glass tube, open at both ends, bent to the shape of the letter U. To use the gauge the left leg is connected with the chimney and the right leg left open to the outside air The air outside the chimney being heavier, it presses on the surface of the water in this leg and forces some of it up higher in the left leg. The difference in the two water levels in the legs represents the intensity of the draft, which is expressed not in ounces. but in inches.

Amount.—Wood requires one-half inch of draft; bituminous coal requires less draft than anthracite. To burn anthracite or slack coal requires about one and one-fourth inches of draft. Two inches is about as much draft as can be obtained with a natural draft, but with a mechanical draft five inches, if necessary, can be easily obtained; the rate at which it is necessary to run the fan depending upon the temperature of the heated gases.

Test.—The standard test for determining the efficiency of combustion is the test for CO_2 (Carbonic ox- The more perfect the combustion, the **higher** being the percentage of this gas. With 2 per cent only of

CO_2 in the gases of combustion, the loss of heat would be as high as 60 per cent, due to the heat being absorbed by the excessive amount of cold air admitted to the furnace. With 10 per cent of CO_2, the loss of heat is reduced to 15 per cent, while with 15 per cent of CO_2, the loss becomes only about 10 per cent.

On the contrary, the greater the per cent of CO (carbon monoxide), the more **imperfect** the combustion, due to the lack of sufficient air.

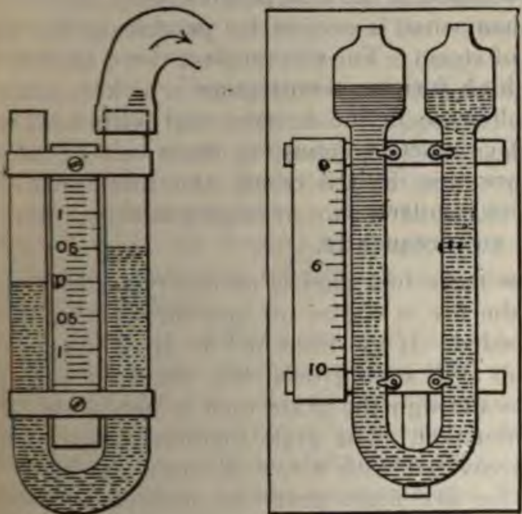
Smoke.—As we have before stated one of the most serious problems that confronts the engineer or fireman is the prevention of smoke which forms from the imperfect combustion of "soft," or bituminous, coal.

Smoke consists of the minute particles of solid carbon left when the hydro-carbons are but partially burned. **Smoke therefore indicates imperfect combustion.**

Smoke Prevention.—In order to prevent smoke we must have complete combustion, and in order to obtain complete combustion, we must maintain a **high temperature** in a properly designed furnace, with ample space for the gases. In an externally fired boiler, this is obtained by making the space above the fire sufficient to allow the gases to become completely consumed. The average distance between the grate bars and the crown sheet is therefore usually made about 2 feet.

If this distance is made too great, some of the effect of the heat is lost; if the distance is too small, the plates are likely to be damaged by being burned, and the combustion is also impaired. In internally fired boilers this presents one of the chief troubles, the combustion and radiating spaces being often sacrificed for a large grate area.

Smoke is produced not so much from improperly constructed furnaces, as from the improper operation



Draft Gauges.
Fig. 41.

or firing of same. In order to maintain the high furnace temperature necessary for the prevention of smoke, the furnace must be properly fired, which requires a competent engineer or fireman to be in charge.

Proper Firing.—A furnace is properly fired when the fuel is consumed in the best possible way, no more being burned than what is needed for producing the required quantity of steam. For this purpose there must be maintained a **high furnace temperature** which requires complete combustion in the furnace, and with such temperature and complete combustion there can be no smoke. To produce this desired result, the fuel must be fired **equally** and **regularly,** not in large quantities, but a **little** at a time and **frequently.**

When more fuel than is necessary is thrown in the furnace, the fire is cooled off and the circulation of the air is impeded. If too little fuel be fired, the fire cannot be kept up as it soon grows thin, thus permitting more air to pass through the grate than is necessary for complete combustion. The grate therefore must always be kept well covered with a fire of equal thickness. Bare spots in the fire must never be allowed to occur, but should be covered over at once, as cold air passes through the fire in such places.

The thickness of the fire must be regulated in accordance with the quality and size of the fuel, in order that only the proper quantity of air should pass through the grates.

In order to regulate the amount of air taken in the furnace, it is not only necessary to see that the grate bars, through which most of the air is taken into the furnace, be properly cleaned, but the chimney damper and furnace doors must also be managed with much skill. The furnace doors should be so arranged as to permit the reg-

causing injuries from contraction and expansion e. The **damper** must never be entirely closed here is fire on the grates, as a dangerous exploight occur. During the operation of the boiler mper should generally be left **open** so as to inthe draft as much as possible. On "banking" the night, that is to push it back on the grate and it over with fresh fuel so as to keep the fire over he morning, the damper is almost closed, it only left open sufficient to prevent any danger from llection of gases.

'hen firing or cleaning out the furnace, the furoors should be kept open as short time as possible, ler to prevent the cold air entering the furnace. urnace doors should never be opened, except when ary, and then only as **short time** as possible. It ommon practice among engineers and firemen to the fire doors slightly open in order to prevent the tion of smoke, this allowing more air to enter the :e. This is a **bad practice** as it means a waste of While it is generally thought that the formation ick smoke in furnaces means the waste of fuel, it een found that this is **not correct**.

'he actual financial loss caused by the escape of

Mechanical Devices.—Many methods have been devised to prevent the formation of smoke, with more or less success.

Among the most important of these mechanical devices, is the introduction of jets of steam into the furnace to more thoroughly mix the air and combustible gases; also fire brick arches, mechanical stokers, down draft furnaces and fuel economizers. Of these methods for smoke prevention, the use of steam jets is by far the most common.

Steam Jets.—The principles upon which all these steam jets depend for their operation are the same, being as follows:

(1) By passing the steam over the fire so as to strike low on the bridge wall the hydro-carbons are not allowed to pass higher than the steam, for the reason that as soon as they come in contact with the moisture of the steam, they are precipitated back into the fire and are consumed.

(2) In forcing a jet of steam into the furnace a greater circulation of gases is produced, thereby securing greater combustion and efficiency from the fuel.

(3) In passing steam over the fire a large amount of oxygen is drawn into the furnace, both above and below it, thereby burning all hydro-carbons before they strike the boiler tubes, and consequently there is nothing to pass off as smoke.

Steam jet blowers can at their best only produce a moderate draft. Experiments made show these jets to use from 8.3 per cent to 21.2 per cent of the steam generated in the boiler to which the jets are applied. In addition to this enormous amount of steam used by them, they are most objectionable on account of the noise

made by them. The only advantage which they possess is the claim that the steam discharged through them prevents clinkers from forming on the grates with certain kinds of coal.

Down Draft Furnaces.—The only mechanical device which has met with any success in smoke prevention, is the **down draft furnace.**

In this furnace there are two grates, one a foot or more above the other. Fresh coal is fed to the upper grate, and as it becomes partially consumed falls through to the grate below where the combustion is completed. The draft is **downward** through the upper grate and **upward** through the lower grate, the connection to the chimney being from the space **between** the grates. While the draft through the upper fire doors and grates is downward the draft through the lower fire doors is a straight draft as is shown in Fig. 42. The volatile gases are carried **down** through the bed on the upper grate, and are burned in the space below it where they meet the hot air drawn upward from the lower grate.

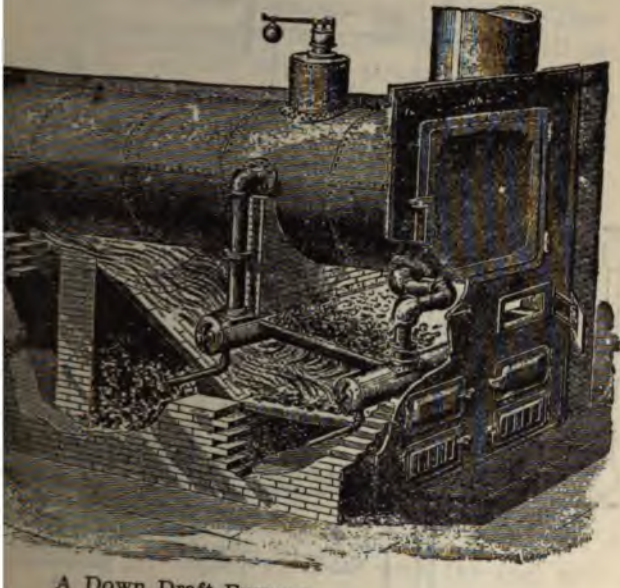
This furnace can be seen from the above description to be a most excellent smoke preventer. The principle upon which it operates, consists in the obtaining of complete combustion by means of the **two** furnaces, thereby securing a thorough mixture of the gas and air, passing them through a mass of burning fuel and finally burning them in a combustion chamber over another mass of incandescent fuel. In Fig. 43 is shown a horizontal tubular boiler, installed with a down draft furnace.

This furnace has been considered above only as a smoke preventer, but in a later chapter its construction and operation will be fully discussed.

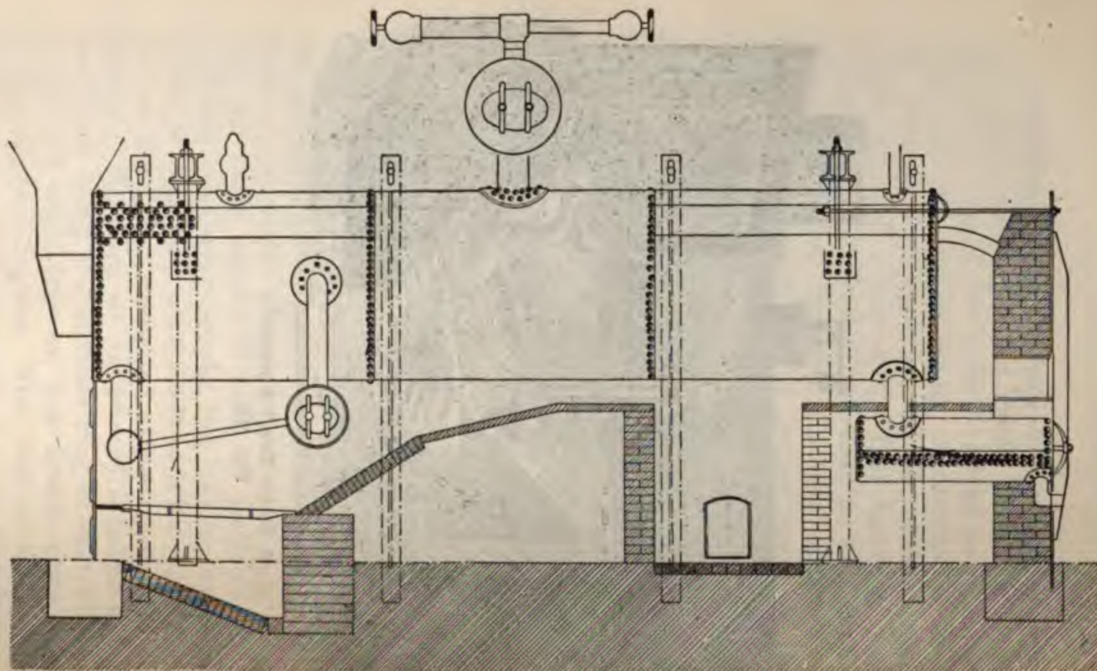
Sufficient Boiler Capacity.—Even with proper fi
it is impossible to prevent smoke from the burnin
bituminous coal if the boiler is **forced** beyond its n
mum capacity. All boilers are constructed so as to
mit them to be forced beyond the **ordinary** work
which they are constructed. This becomes neces
owing to the character of the work or load require
them, as in street car work. In such work the loa
not a constant load, but at certain hours of the
when travel is the greatest the boiler is required t
much more than would be the work of a constant
To meet these requirements boiler makers sell
boilers with the understanding that they can be fo
as much as 33 1/3 per cent beyond their rated capa
It is the **forcing** of boilers beyond their maximum ca
ity which causes to a large extent the formation of sm
in the furnace, due to the imperfect combustion from
hard firing, thereby exceeding the capacity of the b
and furnace.

The only prevention of smoke in these cases i
install a **larger boiler,** or **decrease** the load on the b
in use.

Chimneys.—The proper combustion of the fue
the furnace requires a chimney of proper size and
struction, especially when a natural draft is used. Ch
neys are made usually of brick or steel plates. I
steel they are always circular, but may be made circ
square or hexigonal when made of brick. A steel ch
ney, or stack, is constructed of plates of steel riv
together. The shell so constructed is bolted to a s
foundation using a foundation ring of cast iron, an
is then self supporting; or, it is held in place by m
of guy ropes or cables. The shell is lined with
brick, varying in thickness from 12 to 18 inches at



A Down Draft Furnace.
Fig. 42.



Horizontal Tubular Boiler Installed, With Down-Draft Furnace.
Fig. 43.

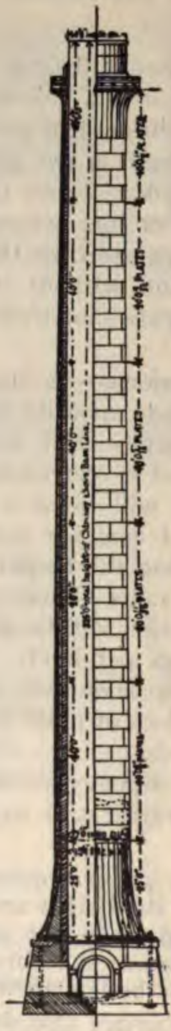
to only a few inches at the top. This lining does d to the **strength** of the chimney, but is used to t the **loss of heat** through radiation from the shell. brick chimney is built in two parts, one, being the shell which is used to resist the wind pressure, other, the lining or core, which is the flue. This r flue is made separate from the external shell in hat it may expand without straining the outer In Figs. 44 and 45 are shown cross-sections of iron ck stacks.

ight and Dimensions.—As the rate of combus- the furnace depends upon the height of the chim- ere a natural draft is used, definite rules or for- have been adopted to determine same. A chim- to 25 feet high will cause a sufficient draft to bout 8 pounds of coal per square foot of grate r hour. **Increasing the height increases the rate bustion.** If the same chimney is made 100 feet e rate of combustion will be about 10 pounds per foot of grate area per hour. By increasing the of this chimney to about 180 feet, the amount of rned per square foot of grate area per hour, could eased to 25 pounds.

e height of the chimney varies with the fuel to ned and the character and work required of the

erefore, the horse power required of a plant deter- to a great extent the height and size of the chim- A chimney of a given height and diameter should n approximate idea of the horse power to be de- d by the boiler or boilers to which it is attached.

he height of the chimney also determines to a great the **amount** of coal that can be burned in the furnace. No. 6 gives the pounds of coal that can be burned ur with chimneys of different heights.



225-Foot Iron Stack, Lined with Brick.
Fig. 44.

The dimensions shown in Table No. 4 have been adopted as the standard height of chimneys for the commercial horse power stated.

Heights of Chimneys.—The following heights are recommended for chimneys, with the coals mentioned: 75 feet for free burning bituminous coal, 100 feet for slow-burning bituminous slack, 115 feet for slow-burning bituminous coal, 125 feet for anthracite pea coal, 150 feet for anthracite buckwheat coal. With such coal as Mt. Olive, a 150-foot stack is recommended. With plants operating 600 or more horse power of boilers, 180 feet is the minimum height, irrespective of the kind of coal that is to be burned. For large plants a 200-foot stack is not excessive.

Gauge and Prices.—The gauge and price are determined by the diameter of the stack. For a stack 10 inches to 18 inches in diameter, use a No. 18 gauge iron, which will cost about 5 cents per pound. From 18 inches to 40 inches diameter, use 18-inch, 16-inch and 14-inch gauge, which will cost 5 cents per pound; and for larger diameters, use 10-inch and 12-inch gauge, costing for No. 12 gauge 3½ cents and No. 10 gauge 3¼ cents per pound.

QUESTIONS AND ANSWERS.

Q. What is combustion?

A. It is a process of rapid oxidation.

Q. What is necessary to carry out this process?

A. It is necessary that the carbon and hydrogen in the fuel combine with the oxygen in the air, and when we get the proper combination the result is perfect combustion.

Q. How is the oxygen necessary for combustion obtained?

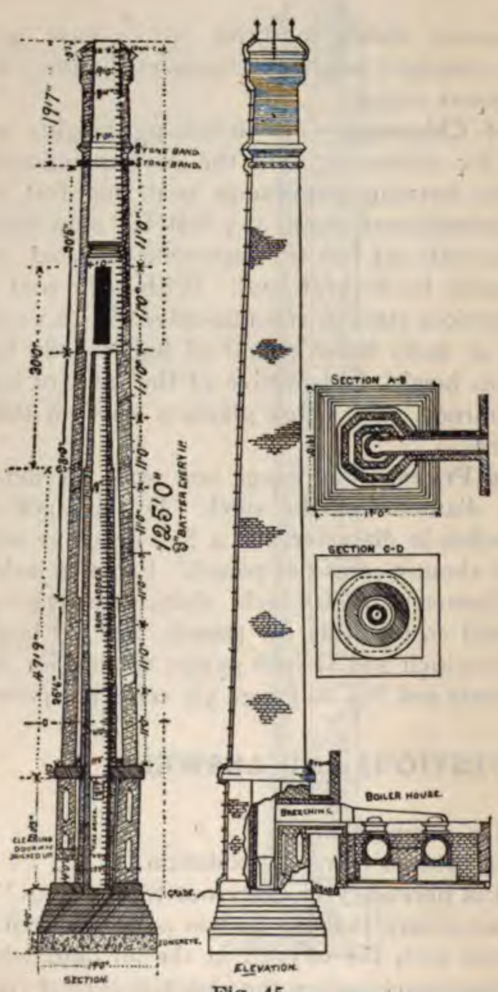


Fig. 45.
125-Foot Brick Stack.

A. It is obtained from the **air** which is forced or drawn into the furnace. From 4.32 pounds of air, only one pound of oxygen is obtained.

Q. What other element is forced or drawn into the furnace with the air?

A. Nitrogen. One pound of nitrogen is contained in 1.30 pounds of air.

Q. Is nitrogen needed for combustion?

A. No. Nitrogen performs no useful work in combustion, and passes through the furnace without changing. It dilutes the air, absorbs the heat and reduces the furnace temperature. It is the chief source of heat loss in furnaces.

Q. When oxygen combines with the carbon and hydrogen of the coal, what gas is formed?

A. Carbonic acid gas (C O 2), and water vapor (H 2 O).

Q. What conditions are necessary for economical combustion?

A. There must be a **sufficient** air supply, **evenly** distributed, and a **high** furnace temperature.

Q. What is perfect combustion?

A. When all the gases developed in the burning of the fuel, **instantly** unite with the oxygen of the air. To secure this there must be a sufficient supply of air and a high furnace temperature.

Q. How much air is required to consume one pound of coal?

A. About 15 pounds, or about 200 cubic feet.

Q. About how many cubic feet of air enters a furnace having a good natural draft?

A. About 530 cubic feet per minute to each square foot of grate surface.

Q. What do you mean by *draft?*

HEIGHT OF CHIMNEYS.

Area Square Feet.	Diameter, Inches.	75	80	85	90	95	100	110	120	130	140	150	175	
		Heights in Feet. Commercial Horse Power.												
3.14	24	75	78	81	...	...	...	...	....	....	....	....	....	..
3.69	26	90	92	95	98	...	...	...	....	....	....	....	....	..
4.28	28	...	106	110	114	117	120	...	....	....	....	....	....	..
4.91	30	...	122	127	130	133	137	...	....	....	....	....	....	..
5.59	32	...	...	144	149	152	156	164	....	....	....	....	....	..
6.31	34	...	...	162	168	171	176	185	....	....	....	....	....	..
7.07	36	...	...	...	188	192	198	208	215	....	....	....	....	..
8.73	40	...	...	...	...	237	244	257	267	279	....	....	....	..
10.56	44	...	...	...	...	287	296	310	322	337	....	....	....	..
12.57	48	...	...	...	...	...	352	370	384	400	413	....	....	..
15.90	54	...	...	...	...	...	445	468	484	507	526	....	....	..
19.63	60	...	...	...	...	...	...	577	600	627	650	672	....	..
23.76	66	...	...	...	...	...	...	697	725	758	784	815	....	..
28.27	72	...	...	...	...	...	...	...	862	902	932	969	1044	..
38.48	84	...	...	...	...	...	...	...	1173	1229	1270	1319	1422	..
50.27	96	...	...	...	...	...	...	...	....	1584	1660	1725	1859	19
63.62	108	...	...	...	...	...	...	...	....	2058	2102	2181	2352	25
78.54	120	...	...	...	...	...	...	...	....	....	2596	2693	2904	3[illegible]

Table No. 4.

A. It is the air supplied to the furnace for the combustion of the fuel.

Q. How many ways can a draft be produced?

A. Two ways. (1) By means of a chimney. (2) By means of a fan or blower.

Q. How is a natural draft produced?

A. It is produced by the difference between the weight of a column of the hot gases contained within a chimney, and the weight of the same bulk of cold air on the outside of a chimney.

Q. What is the object of a chimney or stack?

A. To produce the proper combustion of the fuel in the furnace, and to carry away the spent gases.

Q. How does the chimney or stack do this?

A. By increasing the amount of air that is drawn into the furnace.

Q. Is there any difference between a chimney and a stack?

A. They usually designate the same thing, but when made of steel or iron they are called stacks.

Q. Of what are chimneys or stacks usually made?

A. Of brick, steel or iron, though concrete is coming rapidly into use for this purpose.

Q. What effect on combustion has the increasing of the height of the chimney or stack?

A. Increasing the height increases the rate of combustion.

Q. Why is this so?

A. Because a greater volume or bulk of air inside the chimney is displaced, which requires more cold air to rush into the furnace to fill its place.

Q. What determines the height and diameter of a chimney or stack?

WEIGHTS OF IRON STACKS; WITH GAUGES AND PRICES.

Diam. Inches	Height in Feet.														
	1	20	25	30	35	40	45	50	55	60	65	70	80	90	100
10	7.5	150	188	225	263	300	338	376	414	450	488	526	600	676	750
12	8.5	170	213	255	298	340	383	426	469	510	553	596	680	766	850
14	10.5	210	263	315	368	420	478	526	579	630	683	736	840	946	1050
16	12.5	250	313	375	438	500	563	626	689	750	813	876	1000	1126	1250
18	14.	280	350	420	490	560	630	700	770	840	910	980	1120	1260	1400
20	15.	300	375	450	525	600	675	750	825	900	975	1050	1200	1350	1500
22	16.5	339	413	495	578	660	743	826	909	990	1073	1156	1320	1486	1650
24	18.	360	450	540	650	720	810	900	990	1080	1170	1300	1440	1620	1800
26	37.5	750	938	1125	1313	1500	1688	1875	2063	2250	2438	2626	3000	3376	3750
28	41.	820	1025	1230	1435	1640	1845	2050	2255	2460	2665	2870	3280	3690	4100
30	44.	880	1100	1320	1540	1760	1980	2200	2420	2640	2860	3080	3520	3960	4400
32	46.5	930	1163	1395	1628	1860	2093	2326	2559	2790	3023	3256	3720	4186	4650
34	49.5	990	1238	1485	1733	1980	2228	2476	2724	2970	3218	3466	3960	4456	4950
36	52.5	1050	1313	1575	1837	2100	2362	2616	2877	3150	3412	3674	4200	4724	5250
38	55.	1100	1375	1650	1925	2200	2475	2750	3025	3300	3575	3850	4400	4950	5500
40	58.5	1170	1443	1755	2044	2340	2629	2886	3175	3510	3799	4088	4680	5258	5850
42	61.	1220	1525	1830	2135	2440	2745	3050	3355	3660	3965	4270	4880	5490	6100
48	69.5	1390	1738	2085	2433	2780	3128	3476	3824	4170	4518	4866	5560	6256	6950
54	78.5	1570	1963	2355	2748	3140	3533	3926	4319	4710	5103	5496	6280	7066	7850
60	87.5	1750	2188	2625	3063	3500	3938	4376	4814	5250	5688	6126	7000	7876	8750

Table No. 5.

A. The work required of a boiler, and the character the fuel to be burned.

Q. Does it require a higher chimney or stack to urn anthracite or bituminous coal?

A. Anthracite coal requires a much **stronger** draft burn it than bituminous coal, and hence a **higher** ack.

Q. Of what are the fuels in common use composed?

A. Chiefly of **carbon** with a small percentage of ydrogen, oxygen, and incombustible matter called ash.

Q. How much carbon does anthracite coal conain?

A. From 92.31 to 100 per cent of fixed carbon.

Q. Bituminous coal contains how much carbon?

A. From none to 75 per cent of fixed carbon.

Q. Does wood contain any carbon?

A. Yes; about 50 per cent of carbon.

Q. How is an artificial or mechanical draft proced?

A. It is produced by **forcing** the air into the ash pit y means of fan blowers or steam jets. It is also produced by **sucking** or **drawing** the air into the ash pit and p through the fire by means of **fans**, which create a artial vacuum in the chimney. The air rushes into the urnace to fill this partial vacuum which is formed in he chimney.

Q. What are the advantages of an artificial or mechanical draft?

A. It permits of a much **smaller** chimney to be sed, which of course is a **great saving** in expense. Such a draft is also **easily controlled**, and is **independent** of weather conditions.

Q. What does the presence of smoke indicate?

A. Imperfect *combustion.*

COAL CAPACITY. (Wm. Wallace Christie.)

Diameter, Inches	Area (a) Sq. Ft.	HEIGHT OF CHIMNEY — Pounds of Coal Burned per Hour = 13 × G: 50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.	110 ft.	125 ft.	150 ft.	175 ft.	200 ft.	225 ft.	250 ft.	300 ft.	Equivalent Square Chimney Side of Square
18	1.77	169	182	195	208	...	...	...	...	...	...	...	...	...	...	16
21	2.41	221	247	260	273	...	...	...	...	...	...	...	...	...	...	19
24	3.14	286	312	338	364	390	...	...	...	...	...	...	...	...	...	22
27	3.98	364	403	429	455	494	...	...	...	...	...	...	...	...	...	24
30	4.91	455	494	533	572	611	637	...	...	...	...	...	...	...	...	27
33	5.94	...	598	650	689	728	767	896	...	...	...	...	...	...	...	30
36	7.07	...	715	767	819	871	910	962	1,027	...	...	...	...	...	...	32
39	8.30	...	...	897	962	1,027	1,079	1,131	1,209	...	...	...	...	...	...	35
42	9.62	...	...	1,053	1,128	1,183	1,248	1,326	1,404	1,560	...	...	...	...	...	38
48	12.57	...	...	...	1,456	1,547	1,638	1,716	1,833	2,041	...	...	...	...	...	43
54	15.90	...	...	...	...	1,953	2,067	2,171	2,314	2,587	2,730	...	...	...	...	48
60	19.64	...	...	...	...	2,418	2,548	2,678	2,860	3,198	3,380	...	...	...	...	54
66	23.76	...	...	...	...	...	3,094	3,237	3,458	3,861	4,082	4,368	...	...	...	59
72	28.27	...	...	...	...	...	3,679	3,848	4,121	4,589	4,859	5,200	5,612	...	...	64
78	33.18	...	...	...	...	...	...	4,524	4,823	5,395	5,837	6,097	6,474	6,825	...	70
84	38.48	...	...	...	...	...	...	5,239	5,603	6,253	6,617	7,072	7,501	7,904	8,658	75
90	44.18	...	...	...	...	...	...	...	6,435	7,176	7,592	8,128	8,519	9,074	9,945	80
96	50.27	...	...	...	...	...	...	...	7,319	8,164	8,645	9,243	9,802	10,335	11,323	86
102	56.75	...	...	...	...	...	...	...	8,268	9,217	9,737	10,426	11,063	11,661	12,779	91
108	63.62	...	...	...	...	...	...	...	9,256	10,335	10,933	11,700	12,402	13,078	14,313	96
114	70.88	...	...	...	...	...	...	...	...	11,518	12,181	13,026	13,819	14,573	15,964	101
120	78.54	...	...	...	...	...	...	...	...	12,766	13,494	14,443	15,314	16,146	17,680	107
132	95.03	...	...	...	...	...	...	...	...	15,444	16,328	17,472	18,525	19,526	21,398	117
144	113.10	...	...	...	...	...	...	...	...	18,382	19,435	20,800	22,061	23,244	25,467	128

Table No. 6.

Q. What is necessary to prevent the formation of smoke?

A. The proper amount of oxygen. To obtain more oxygen, it is necessary that more air enter the furnace. A high furnace temperature is also necessary, so that all gases formed and solid particles may be **completely burned,** before leaving the furnace.

Q. Can **too much** air be permitted to enter the furnace?

A. Yes. Too much air will **lower** the temperature of the furnace, causing not only a needless **waste** of heat, but finally reducing the temperature of the furnace below the point of ignition.

Q. What is a minimum point to which the furnace temperature should be allowed to fall?

A. Never below 1,800 degrees Fahrenheit, as that is the ignition point of the combustible elements in fuel.

Q. Should the air enter above or below the fire in the furnace?

A. Both above and below the fire, but the larger amount should be taken from **below** the fire, through the ash doors and up through the grate bars.

Q. How should it enter the furnace above the fire?

A. Through the fire doors, hollow tiles or through openings in the bridge walls.

Q. Why is it best to take the air supply from below the grate?

A. Because the air is then highly heated in passing through the fuel bed. It also comes into immediate contact with the gases as soon as they are formed, thoroughly mixing with them in the hottest part of the furnace and thus insuring complete combustion.

Q. What is the objection to taking the air above the grate?

A. The cold air through the fire doors comes in quick contact with the heated shell or boiler plates, thus chilling them and causing unequal contraction and expansion.

Q. How is air generally introduced above the grates?

A. Through a perforated inner door, or a damper arrangement in the outer fire door.

Q. What is the object of using steam jets in a furnace?

A. To prevent smoke by supplying the furnace with more air, as air is drawn in through the jets with the steam.

Q. Does the decomposition of the steam thus introduced into the furnace, add any heat to the furnace?

A. No, none whatever, as the heat taken from the furnace to decompose the steam into oxygen and hydrogen, is simply replaced by the burning of the hydrogen.

Q. How is the formation of smoke best prevented?

A. By proper firing.

Q. How does this prevent smoke?

A. By firing the furnace a little at a time and often, a sufficiently high furnace temperature can be maintained to burn all the gases and the unconsumed particles of carbon as soon as they are formed. To do this, the grates must be kept free for the passage of air, and this can only be done by proper firing. The coal must be charged in small lumps and evenly distributed over the grate bars so as to have a clean, even fire.

Q. When a furnace is properly fired what takes place?

A. The gases distilled from the fresh coal thrown in on front of grates, will be ignited while passing over the incandescent coals on rear of grates, and the hydro-

carbons will be entirely consumed instead of being discharged from the chimney as smoke. After the coal in front has been "coked" as it is called, it should then be pushed to the rear and a fresh supply of coal should be charged on the front of the grates.

Q. How soon should fresh coal be thrown in the furnace?

A. Not until the whole fire has reached a white heat.

Q. Why should the fire doors always be closed as quickly as possible?

A. To prevent the entrance of cold air.

Q. What is the only smoke preventor?

A. A good fireman.

Q. What is the only good mechanical device for smoke prevention?

A. A down draft furnace, but it will produce smoke if improperly fired.

Q. Should the fuel ever be charged on the lower grates of a down draft furnace?

A. No, for it will then be the same as a straight draft furnace, and will probably produce smoke.

Q. What are the disadvantages of a down draft urnace?

A. The additional cost, additional space required, ickling of the water grates and care required.

Q. What are the disadvantages to the use of steam s for smoke prevention?

A. They rob the boiler of too much steam, and o make a very objectionable noise. They cannot be ed on low pressure boilers, and it is boilers of this aracter that produce most of the objectionable smoke. is is caused partially by the low temperature of the nace.

Q. Why cannot steam jets be used on low pre sure boilers?

A. The steam pressure is not high enough to o erate them. For this reason they cannot be used on hig pressure boilers until about 50 pounds of steam has bee raised. This also prevents their use when the boiler first fired, at which time most smoke is produced.

Q. Can a good fireman **always** prevent smoke?

A. No, not when a boiler is being worked beyon its maximum capacity.

Q. What is meant by the maximum capacity of boiler?

A. The greatest amount of steam which can produced from the boiler under any conditions, which a safe and economical.

Q. Should a boiler be worked at all times at maximum capacity?

A. No, but only at its rated capacity, which is u ally 33 1/3 per cent less than its maximum capacity.

Q. Can a boiler be forced beyond its maximum pacity without producing smoke?

A. No, even with the best firing there cannot complete combustion, hence the unconsumed particles carbon will escape with the unburned gases.

Q. What is the **only** remedy for insufficient boi capacity?

A. A larger or better boiler, or to **decrease** the lo on the boiler in use.

Q. How is the value of different fuels fixed steam raising purposes?

A. By the amount of water one pound of the fu will evaporate.

Q. Can you give an example of this?

A. Yes, one pound of coal has an average evaporative capacity of 14.69 pounds of water, or, one pound of peat, if all the heat is utilized, will evaporate 7.41 pounds of water.

Q. How can one obtain the different values of fuels?

A. From tables of evaporation, such as given in Table No. 12.

Q. How many pounds of **good coal** should be used per boiler horse power per hour?

A. About 3½ pounds.

Q. How many cu. ft. of **natural gas** should be used to get one boiler horse power?

A. About 40 to 45 cu. ft.

Q. How many pounds of **oil** should be used per boiler horse power?

A. About 1¾ pounds of oil.

Q. At what cost can natural gas be burned with coal at $2.00 per ton?

A. At 7½ cents per 1,000 cu. ft.

Q. At what cost can **oil** be burned with coal at $2.00 per ton?

A. At 60 cents per bbl., or about 1½ cents per gallon.

Q. What is the **theoretical** evaporative power of oil?

A. From 19 to 22.7 pounds of water per pound of oil.

Q. What is the **practical** evaporative power of oil?

A. About 12 pounds of water per pound of oil.

Q. Why is **oil** the ideal fuel under boilers?

A. On account of the perfect combustion attainable, and the absence of soot, ashes and all dirt. It also permits the fire to be at all times under **perfect** control.

Q. How many pounds of **dry wood** is equal to one pound of **good** anthracite or bituminous coal?

A. About 2½ pounds.

CHAPTER IV.

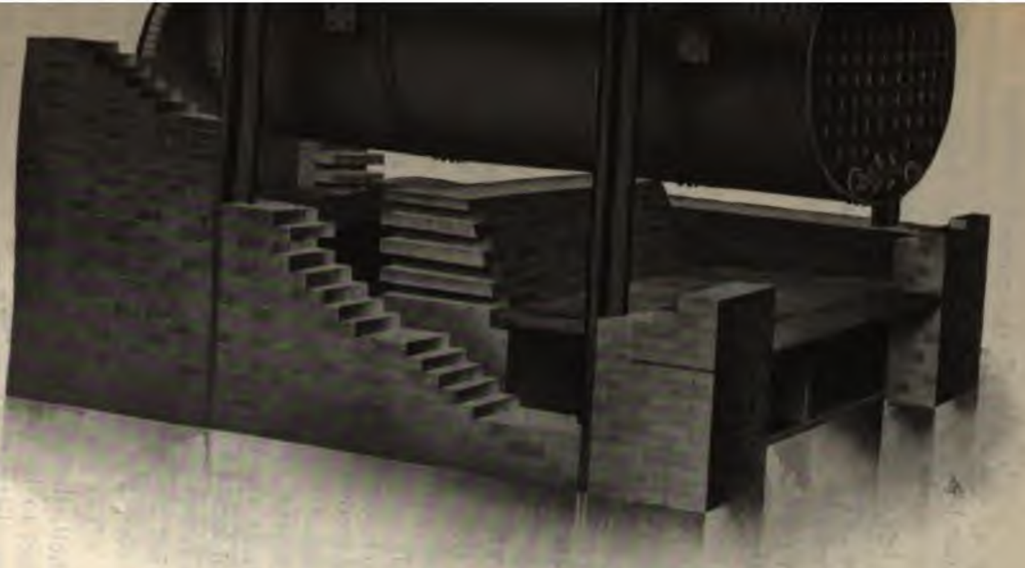
BOILER INSTALLATION.

Boiler Setting.—In boiler setting there are three things necessary for both safety and economy in the operation of boilers, viz.: (1) a firm support for the boiler shell; (2) properly arranged space for furnace and ash pit; (3) a protective covering that will prevent the loss of heat by radiation from the boiler as far as possible.

Supporting Boilers.—There are two principal methods for supporting boilers, viz.: by **brackets** riveted to the shell plates, and by supporting them from overhead girders by means of hooks, rings, etc.

Externally Fired Boilers.—Such boilers are usually supported by cast iron lugs riveted to the shell and resting on the side wall, or they may be suspended from overhead girders by means of hooks or rings. In supporting boilers with long shells, it is necessary to arrange so that each support will bear its proper proportion of the load and at the same time allow the boiler to expand freely under all changes of temperature.

Fig. 46 shows a horizontal tubular boiler with suspension settings. Such setting consists of two girders, each made from two steel I beams, the whole resting on four extra heavy cast iron columns of a certain construction. The cast iron columns are preferred to those of steel, as the steel are more apt to warp and spring. The principal advantage in the suspension setting, is that from time to time as it becomes necessary to tear down the brick walls, or to reset the fire brick, the boiler, being absolutely independent of the brick work, is not disturbed and needs no blocking.



Horizontal Tubular Boiler with Suspension Settings.
Fig. 46.

Fig. 47 and 48 show the correct settings of horizo tal tubular boilers, while the standard measurements f settings is shown in accompaning table of measur ments, being Table No. 7.

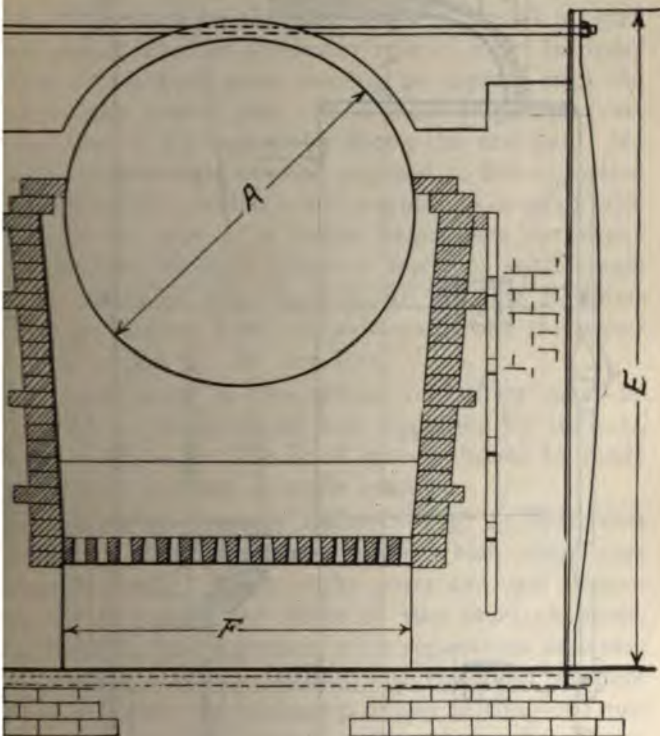
Fig. 43 shows the complete settings of a horizont tubular boiler with a **down draft furnace.**

In Fig. 47 is shown the ordinary settings for horizor tal boilers.

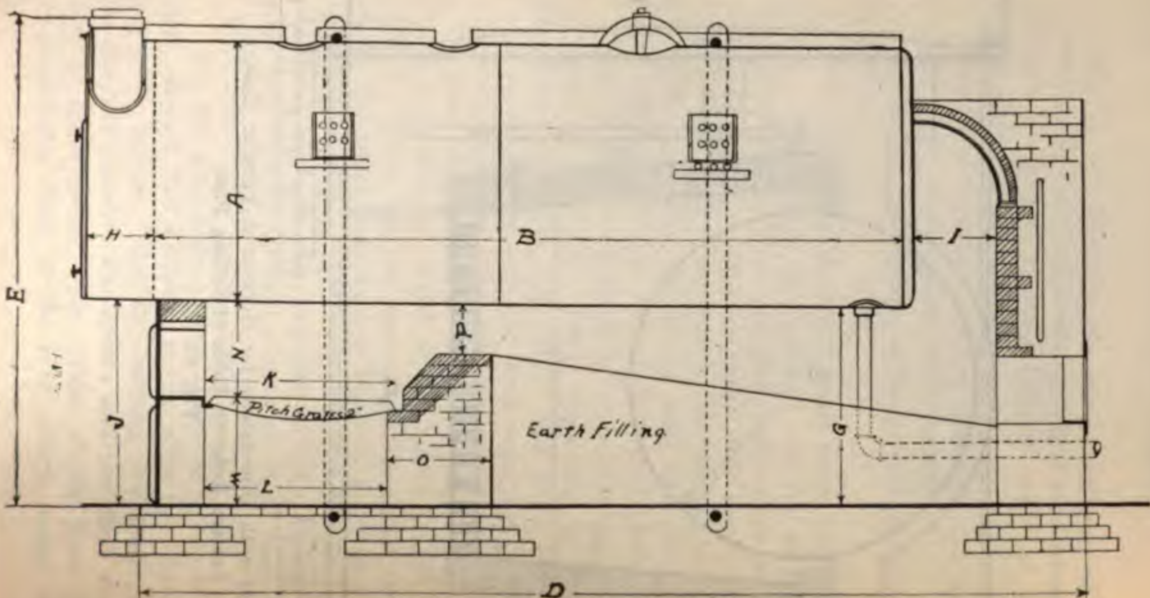
The foundation is heavy stone work laid to a dept of 3 or 4 feet below the surface. On top of this is lai the brick work. The side and rear walls are doubl with a 2-inch air space between the inner and out parts. The inside wall next to the furnace is faced wi fire brick, as is also the bridge wall and all portions direct contact with the flames or heated gases.

The boiler is supported by cast iron lugs riveted the sides of the shell. These lugs rest on iron pla placed on top of the side wall. The front lugs rest rectly on the plates, but the back lugs rest on **rollers** 1-inch round iron. This permits a free expansion ar contraction of the boiler. The rear wall is usually inches from the rear head of the boiler, so as to allo sufficient space for the hot gases to enter the tube Above the tubes this wall is built in to meet the hea and forms a roof for this combustion chamber. In orde to remove the dirt and soot that collects mostly at th point and also to provide means of inspection, there a door placed in the rear wall.

The fire grates are placed about 24 inches below th shell, though this distance varies with the character c fuel to be burned. For the burning of bituminous coa the distance between the grates and the shell should b from 24 to 26 inches. The grates should have a fall c 3 inches from front to the rear, which makes it easi



ings with Dimensions for Horizontal Tubular Boilers.
Letters Refer to Table of Setting Plan.
Fig. 47.



Settings with Dimensions for Horizontal Tubular Boilers.

to clean the fire from below and at the same time facilitates the admission of air to the rear of the furnace.

The brick work of the side walls is closed in with the shell at the level of the upper row of tubes in order to prevent the heated gases coming in contact with the shell above the water line. It is most important that the water line of all boilers be above the fire line. No part of the shell should ever be exposed to fire or heated gases of combustion which is not completely covered with water. The fire line of a boiler determines the water line. In boilers without tubes or flues, or with steam drums as on water tube boilers, the fire line is determined by the closing in of the side walls, and the water line is determined by the fire line.

The brick work of the setting of boilers must be strengthened by **buck staves** held together by tie-rods, as shown in Fig. 47. The buck staves should be made of wrought iron channel or angle irons.

Suspension of Tubular Boilers.—Fig. 49 illustrates a plan of suspending tubular boilers which sometimes recommends itself. The upright posts are cast iron—the horizontal beams are made of two steel channels, back to back, bolted together, with separators between. The suspension bolts are round, with nuts and washers at the top, allowing the taking up of any settling of foundation. The brickwork around boiler can be entirely removed without disturbing boilers or connections. The usual lugs on boilers are replaced with forged loops, as shown.

The brick walls should never be built solid, but always with an **air space** left in them of at least 2 inches in width in order to prevent the conduction of heat to the outer walls, as air is a non-conductor of heat. This air space is shown *in Fig. 50 of Double Boiler* Settings.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
48	14'-0"	7'-11"	18'-0"	8'-0"	43	45	14¾	18"	46½	54	51	22½	24	24	10
48	16'-0"	7'-11"	20'-0"	8'-0"	43	45	14¾	18	46½	54	51	22½	24	24	10
54	14'-0"	8'-5"	18'-2"	9'-0"	49	46½	16½	20"	48½	48	45	24½	24	24	12
54	16'-0"	8'-5"	20'-2"	9'-0"	49	46½	16½	20"	48½	54	51	24½	24	24	12
60	14'-0"	8'-11"	18'-2"	9'-6"	55	46½	16½	20"	48½	54	51	24½	24	26	12
60	16'-0"	8'-11"	20'-2"	9'6"	55	46½	16½	20"	48½	54	51	24½	24	26	12
60	18'-0"	8'-11"	22'-3"	4'-6"	55	46½	16½	20"	48½	60	57	24½	24	26	12
66	16'-0"	9'-5"	20'-4"	10'-6"	61	48½	17½	22"	50½	54	51	24½	26	26	12
66	18'-0"	9'-5"	22'-4"	10'-6"	61	48½	17½	22"	50½	60	57	24½	26	26	12
72	16'-0"	9'-11"	20'-6"	11'-0"	67	48½	19½	24"	50½	60	57	24½	26	30	12
72	18'0"	9'-11"	22'-6"	11'-0"	67	48½	10½	24"	50½	66	63	24½	26	30	12

Table of Measurements for Settings of Horizontal Tubular Boilers.
Letters Refer to Setting Plans, Fig. 47 and Fig. 48.
Table No. 7.

Self Contained Boilers.—Vertical and locomotive type of boilers, and practically all internal fired boilers, are self contained and require no setting. The vertical tubular boiler rests on a cast iron base which forms the ash pit. Locomotive, or portable boilers as they are called when used for stationary work, are supported on cast iron saddles and skids, as shown in Fig. 10.

Settings of Water Tube Boilers.—The settings for water tube boilers are essentially similar to the settings of horizontal tubular boilers. The settings for these boilers vary only in the baffling of the gases, and the tiling required to conduct the gases in such a way as to keep them in contact with the tubes. Fig. 52 shows a water tube boiler installed, with measurements and proper settings for same. Fig. 53 shows the ordinary type of a water tube boiler in course of erection, while Fig. 54 shows the Sterling water tube boiler in course of erection.

Boiler Fronts.—Boiler fronts are made in many different styles, the four principal styles or designs being;

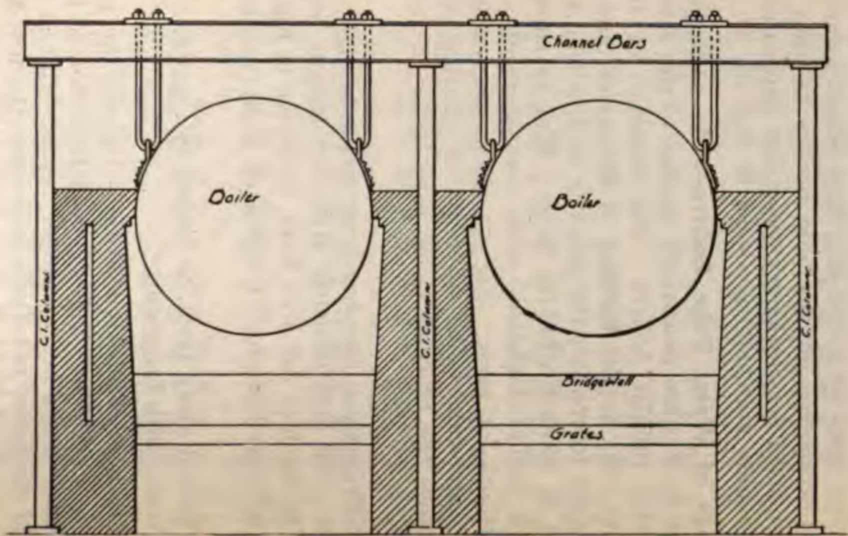
(1) The flush or full-arch front, as shown in Fig. 55.

(2) The over-hanging or half-arch front, as shown in Fig. 56.

(3) The cut-away front, as shown in Fig. 57.

(4) Fronts with breeching.

The Flush or Full-Arch Front.—This is the most generally used style, and gives good satisfaction so long as the furnace walls are in proper repair. But at any time should the brick fall away from over the fire door, it will leave exposed to the heat, portions of the dry sheet causing it to be burned or otherwise injured by the heat, and probably starting a leak around the front row of rivets. A common form of this front is shown in Fig. 55.



Suspension of Tubular Boilers.
Fig. 49.

Over Hanging or Half-Arch Front.—In this style of front the above objection to the full-arch front is entirely avoided, as the dry sheet projects out into the boiler room and is not exposed to the furnace heat. Should the fire brick fall away, no damage can be done since the sheet which would then come in contact with the heat is entirely protected by water on the inside.

This front setting has a further advantage that it occupies less floor space than the full-arch, and hence will require also a smaller number of common brick and fire brick.

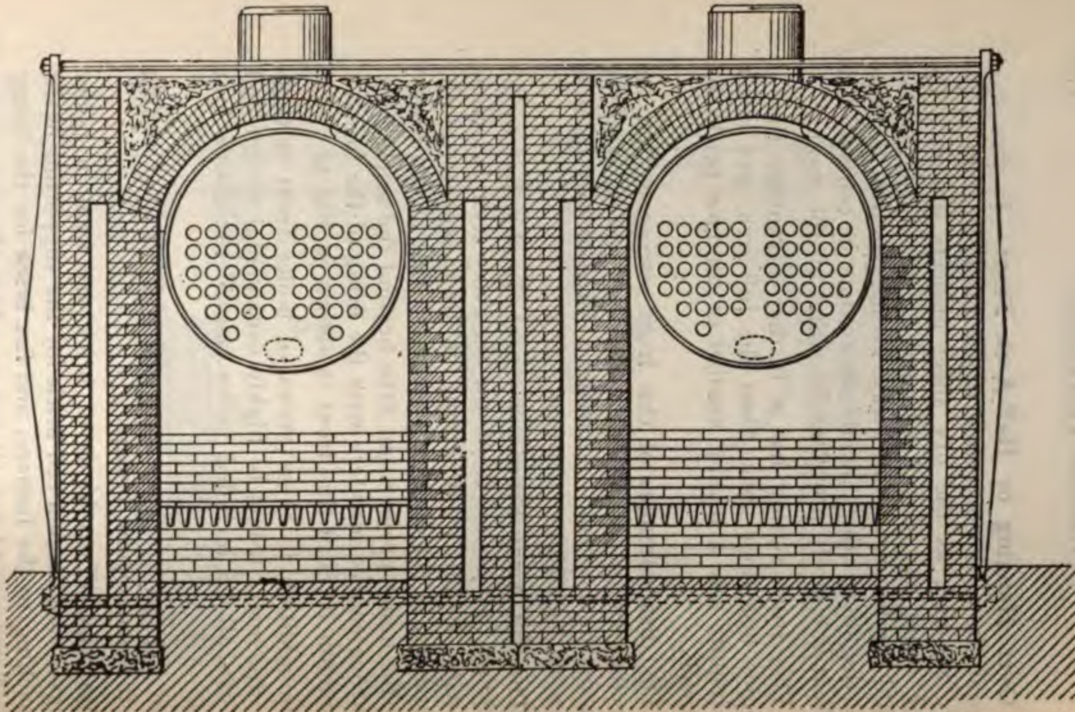
The **disadvantages** of this front setting is that the projecting smoke-box interferes to some extent with the work of the fireman. A common form of this front is shown in Fig. 56.

The Cut-Away Front.—To meet the objection to the projecting half-arched front, the cut-away style has come into use. In this front setting the lower portion, or the front sheet, is cut obliquely away, so that at the lowest point the boiler projects but little beyond the brick work, and hence cannot interfere with the firing of the furnace. A common form of this front is shown in Fig 57.

In addition to these styles of boiler front settings there are many fronts of highly ornamental design, but they can all be included under one of the above four styles.

In Fig. 58 is shown the usual style of front setting used for **water tube boilers.**

Material.—Two kinds of brick are used in boiler settings—the **common red brick** for the supporting walls and backing to the furnace, and **fire brick** for the lining of the furnace and for all points where the fire or hot gases come in direct contact with the furnace or flues.



Cross Section of Double Boiler Setting, Showing Air Space.
Fig. 50.

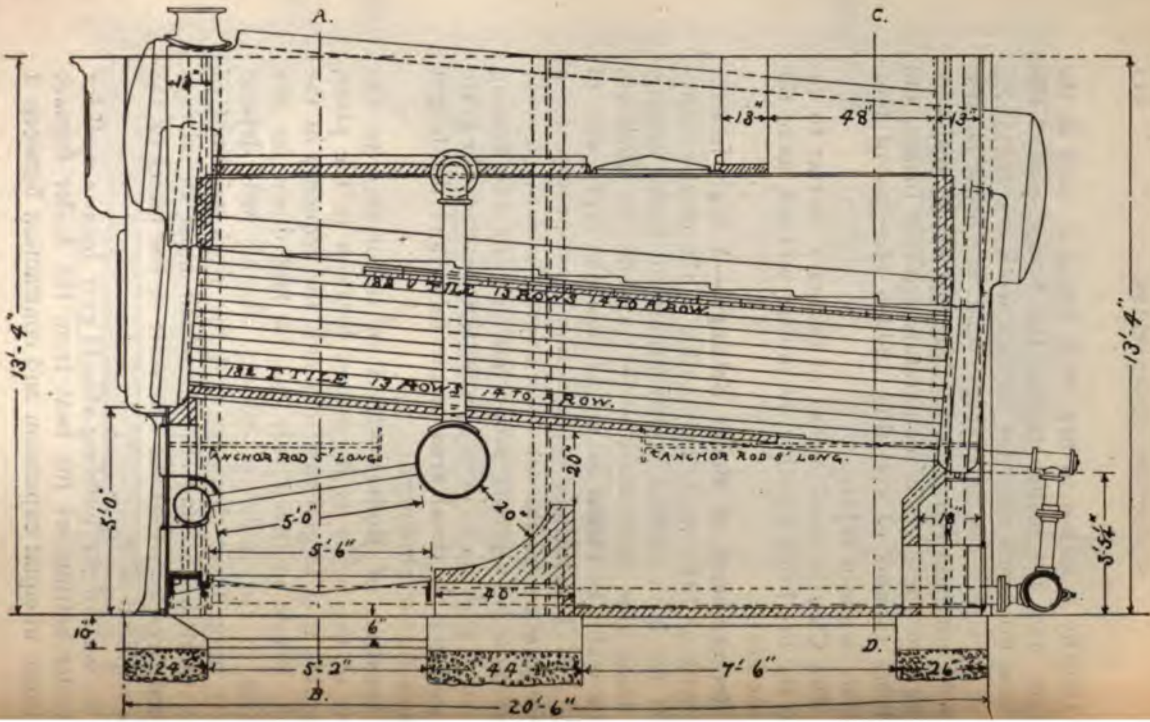
Usually 9 inches of fire brick lining is used in the nace, and $4\frac{1}{2}$ inches behind the bridge wall. The mon fire brick used for furnace work are $9 \times 4\frac{1}{2} \times 2\frac{1}{2}$ ches in size. The advantages that fire brick possess er the common red brick are, their power to resist for long time the highest temperature without fusion, and being capable of resisting sudden changes of temrature without injury.

Fire Clay is used instead of ordinary mortar to cent the fire brick together, as mortar will not stand the tense heat.

Requirements of Boiler Settings.—A high furnace at with as little waste as possible is the chief requireents for both furnace construction and boiler setting. obtain this there must be, (1) a sufficient thickness the walls to **retain** as far as possible every unit of at. (2) The furnace construction must provide for a per **mixture** of the air drawn into the furnace. (3) ere must be a proper **proportion** of grate and heating face. (4) Also, a correct proportion between the grate face, and the **total area** of the tubes and the height area of the chimney.

Location of Boilers.—Next in importance to the ety of the boiler is its proper location in the plant, on this to a large extent depends the **economy** of the nt. While no fixed rule can be laid down for the ation of the boiler or boilers, as this will depend gely upon their character and the work required of em, there are certain things which must be always oided irrespective of the character of the boiler or the ork required of it.

No wall of the building should ever form a wall for e boiler setting, as the heat from the boiler furnace ll cause unequal expansion and contraction between it



A.
C.
B.
D.
13'-4"
13'-4"
18"
48"
13"
5'-0"
5'-6"
5'-2"
7'-6"
20'-6"
20"
40"
6"
24"
44"
26"
18"
3'-5¼"
ANCHOR ROD 5' LONG
ANCHOR ROD 8' LONG
13 ROWS 14 TO A ROW.
14 TO A ROW.

and the other supports of the boiler, causing the wall soon to crack and become unsafe.

The boiler room should be made of ample height and dimensions, and on a level with the engine room, which room should be separated from it by a brick partition. There should be as little distance as possible between the boiler and the engine in order to avoid the waste from condensation as much as possible; and all parts of the boiler and engine room should be easy of access and so arranged as to be at all times within full view of the engineer. There should be sufficient ventilation provided both for the health and comfort of the attendants.

The blow-off valves should never be placed outside of the building, but either boxed in or packed with some non-combustible material where they can always be accessible to inspection, as should be all valves and attachments to the boiler.

All valves should be kept carefully packed to prevent leaking, as permitting the valves to leak not only ruins the valve in a short time but causes a large waste of fuel.

Installation.—The installation of a complete boiler plant includes the setting of the boiler or boilers, and the location and arrangement of the various accessories of same; such as feed water heaters, purifiers, separators, feed pumps, injectors, etc., and should the plant be large and more elaborate, the installation would then also include the installing of economizers, mechanical stokers, coal conveyors, etc.

A small plant, though, often consists only of one boiler and a boiler feed pump, but the stationary engineer should be prepared to *install and operate* any char-

A Water Tube Boiler in Course of Erection.
Fig. 53.

cter of plant, irrespective of its size, that he may be alled upon to take charge.

Piping.—All pipes which through accident or other-ise might cause a shut down of the plant, should be in **uplicate.** For the larger sized pipe flanged joints should e used, as such joints can be more easily and quickly andled than screwed joints. All pipes should be ar-ranged so as to be easy of access for repairs, and should e placed **below** the floor wherever it can be done, al-ugh overhead pipe is much more accessible.

While it is not necessary that an engineer should a good steam fitter, he should nevertheless have a od knowledge of **steam fitting,** especially of pipes and lves. The first work an engineer does on taking arge of a plant, is to ascertain the course and condition all the water, steam, blow-off and drain pipes.

While the construction and material of pipes differ great deal according to the work for which they are be used, most all pipes used in a steam plant are ade of **wrought iron.** Formerly cast iron pipe was most exclusively used in steam plants, but the high eam pressure now required, has necessitated the use of ronger pipe and one that can be more easily handled. he advantages of wrought iron pipe are its lightness, strength and the ease with which various lengths can obtained.

Pipe manufactured from double thick iron is called a heavy pipe, or X pipe, while pipe double the thick-ss of this is called XX pipe.

Size of Piping.—The size of pipes is designated by **internal diameter,** while that of **boiler tubes** is desig-ted by the external diameter.

The Stirling Water Tube Boiler in Course of Erection.
Fig. 54.

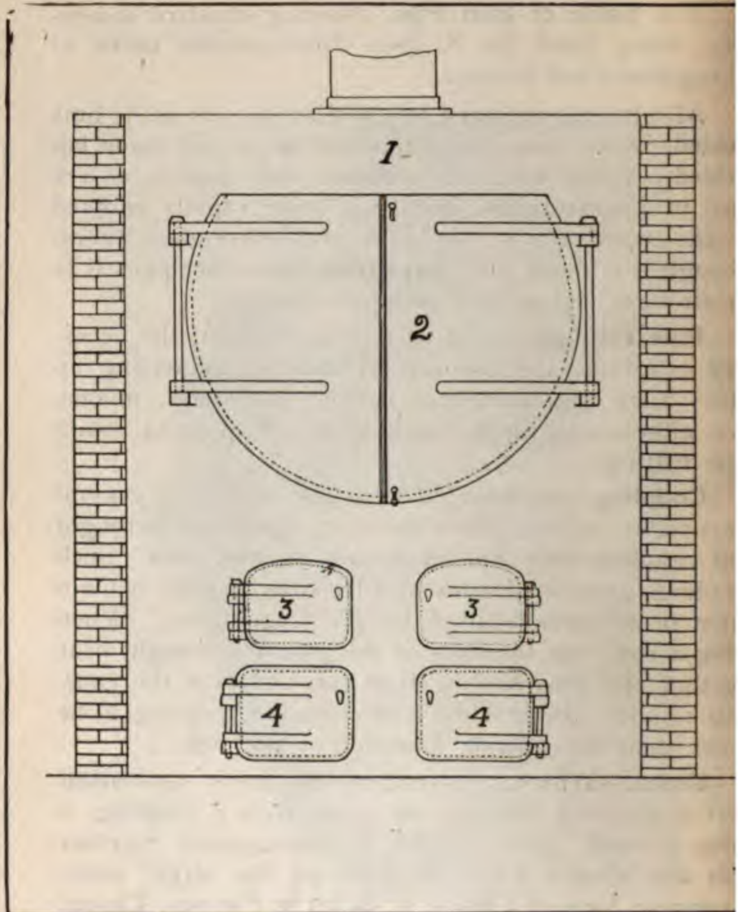
The **Table of Iron Pipe,** showing standard dimensions, being Table No. 8, gives data especially useful to all engineers and firemen.

All pipe 1¼ inch and less in diameter are made **butt welded,** while sizes 1½ inches and larger are made **lap welded.** While but little seamless steel pipe is as yet used in a steam plant, its use is being rapidly adopted in the construction of boiler and water-grate tubes. Though it is much more **expensive** than other pipe, it is far stronger, lighter and more serviceable.

Pipe Fittings.—By pipe fittings is meant the necessary couplings and connections used in connecting up pipe. Such pipe couplings consist of flanges, unions, tees, elbows and nipples as shown in Fig. 59 of Steam Pipe Fittings.

Coupling.—In wrought iron pipe work, the general practice in making joints between pipes is a wrought iron coupling with tapered threads at both ends. Such couplings are used for the smaller sizes of pipe, while a union or a flange is used for the larger sizes. When using a coupling, the ends of the pipe are brought near together and the coupling then screwed over the ends. This requires the inside diameter of the coupling to be larger than the outside diameter of the pipe.

Union.—Where a stronger and more convenient joint is required than can be made with a coupling, a union is used. This consists of three pieces, together with the washer which is used on the larger sizes. A common form of a union is shown in Fig. 60. Unions are also made with ground-joints and the washer is then not needed, as a tight joint can then be made without it. When the pipes are above 4 or 5 inches in diameter, a **flanged union** should be used. This union consists of two circular cast iron flanges with a requisite



Flush or Full-Arch Boiler Front.
Fig. 55.

number of holes for bolts through each, and a large central hole tapped to receive the threaded ends of the pipe. The two flanges are screwed onto the ends of the pipe and then bolted together, thus making a much stronger and tighter joint than is possible with the ordinary coupling.

The adbutting faces of the flanges are generally "faced," or turned smooth, and a **gasket** placed between them to prevent leaking.

Elbow.—In order to avoid sharp angles in joining together pipe, which would cause friction in the flow of the liquid or gas through them, an elbow or ell as it is usually called, is used to make the necessary turns in the course of the piping.

A **street-elbow,** or street-ell, is an elbow threaded externally at one end so that it can be used as a connection between different size pipes.

Tee.—When a second pipe is to be joined to a line of pipe at an **angle** to it, usually a right angle, a tee or "T" as it is abbreviated, connection is used.

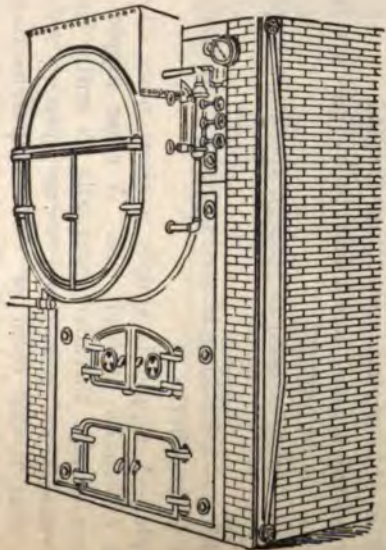
A **cross-tee** is used when **two** such pipes are to be joined to a line of piping.

Plug.—A plug is used to stop an aperature in plates or pipes.

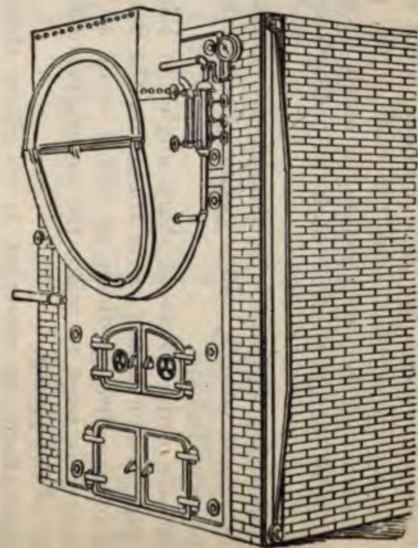
Bushing.—A bushing is used to **reduce** one size pipe in a line to another.

Nipple.—A nipple is simply a short piece of pipe threaded externally at each end. A **close nipple** is a short piece of pipe threaded externally its **entire** length.

Valves.—A valve is a lid to an opening so constructed that it can open or close communication in same. Among the **varieties** of valves may be classed the cock, the slide valve, the poppet valve, the pump and the clack valve.



Over-Hanging or Half-Arch Boiler Front.
Fig. 56.



Cutaway Boiler Front.
Fig. 57.

A valve always has a seat, which is simply the opening on which it rests. They are usually operated by a circular handle fitted to a spindle, by the turning of which the valve can be opened or closed.

Cock.—A cock is a conical plug slotted and fitted with a handle for turning the slots, or openings, in line with the opening of the pipe. Fig. 262 illustrates the common form of a three-way cock used in steam work. A cock is a valve, but a valve is not necessarily a cock. When the opening is closed by moving the lid or disk across the opening of the pipe with or without rotation, it is a valve. When it is opened or closed by turning through an **angle**, it is then a cock. Cocks are mostly used on the blowoff pipe of boilers; asbestos packed plug cocks being generally used for this purpose, as such packing overcomes the difficulty of moving the plug when the cock has been closed for some time.

Globe Valve.—The globe valve, a view of which is shown in Fig. 61, derives its name from the **shape** of the case or bonnet enclosing the valve. This case is divided into two parts by a partition with an opening through the horizontal part. The fluid or gas enters at the right and passes **up through** the opening and out at the left. It is closed by screwing down the valve on the opening which forms the seat. A stuffing box around the spindle or stem which is used to screw down the valve on the seat, prevents its leaking. If the disc or valve is round, it is called a disc valve. This disc may be made **removable**, so as to permit it being easily removed when worn from use so as to cause it to leak.

Globe valves must always be set so as to close **against** the flow, so that the valve could be opened should it become detached from the stem or spindle.

Ordinary Front for Water Tube Boilers.
Fig. 58.

This also permits the valve to be packed without shutting off the entire flow through the pipe, as this might necessitate the shutting down of the plant.

The **disadvantages** of the globe valve is the **resistance** or friction caused by the two turns, which are almost at right angles, necessary to be made by the liquid or gas in passing through the valve. In Fig. 62 is shown a section of a Crane Globe valve. In Fig. 63 is shown the Jenkins Globe Valve, which is a standard valve among engineers.

Gate Valve.—To overcome this objectional friction in a globe valve, the gate valve is constructed as shown in Fig. 64. In this valve by turning the stem or spindle, the wedge-shaped disc is moved vertically across the opening or orifice. The disc has cast on its lower side, a projection that rests on a corresponding projection which is cast with the valve body. These two projections form a stop for the disc and hold it tightly in place. As the disc moves vertically up and down, the valve may be put in so as to receive the pressure on either side. In Fig. 64 is shown in section this valve as made by the Western Tube Co.

Angle Valve.—This style of valve is used at the junction of two pipes at a right angle. Its construction otherwise is similar to the globe valve, and, like that valve it should be attached to the pipe in such a manner that the pressure from the liquid or gas will be **up** against the disc and not on it. This requires the valve to always close **against** the pressure.

Check Valve.—This valve is designed to permit the flow of liquids or gases in one direction only, and to prevent any return flow. There are several forms of check valves manufactured, the most common form being known as the **Globe Check.**

45° Elbow.

Elbow.

Tee.

Cross.

Coupling, R. H.

Bushing.

Standard Steam Pipe Fittings.
Fig. 59.

In this form, the valve is a solid disc of metal which held to its seat by wings which are placed on the disc th above and below. The fluid or gas passes in under e disc, and raising it from its seat flows on through the same direction. Its return is prevented by the essure being all on top of the disc, which as seen from e construction will close the opening at once by forcing e valve on its seat.

Another common form of this valve is the **swing eck** as shown in Fig. 65. The valve disc is attached an arm that swings on a pin. The passage of the id or gas through the valve swings open this disc. ould the flow return in the opposite direction, the prese at once closes this disc and holds it to its seat.

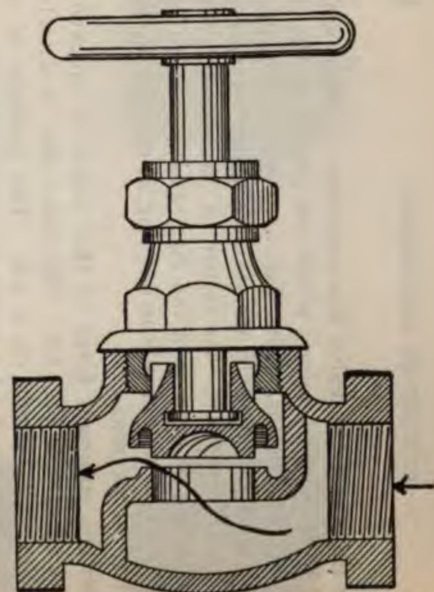
These two forms of check valves are chiefly used working in a **horizontal** position. For **vertical** work construction of the valve is different, but its operan remains the same.

Reducing Valve.—Where steam is desired at a lower essure than that of the boiler, a reducing valve is used. is result is accomplished by automatically throttling e steam, so as to reduce the pressure and at the same me maintain a constant pressure in the steam pipes.

There are several forms in general use. In Fig. 66 he ordinary operation of this valve is shown, in which he valve is held open by the spring and levers until he steam pressure at the exit presses on a diaphragm fficiently to close it. Fig. 66 is a sectional view of the Davis Pressure Regulator or Reducing Valve.

The Layout of Steam Plants.—As a rule the stationary engineer is not called upon to design and superintend the installation of a steam power plant, but only to **operate** same safely and economically. But he should be able to fully understand the **layout** as well as the

A Pipe Union.
Fig. 60.



Sectional View of a Globe Valve.
Fig. 61.

operation of any plant which he may be called upon to take charge.

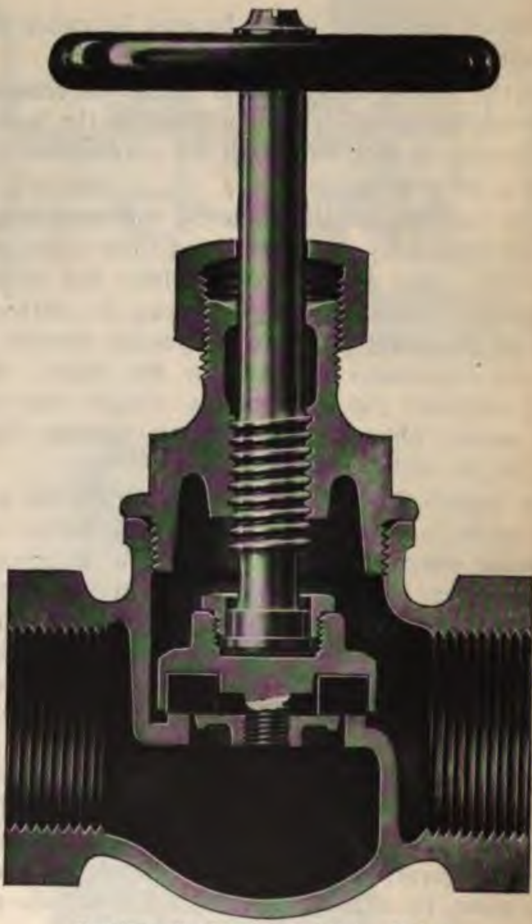
By the layout of a plant is meant its **complete design**, including every detail not alone of the boilers, engines, dynamos, etc., but of all the accessories to same, including the piping.

This work is usually done by the **consulting engineer**, the stationary engineer being only called upon to operate the plant after it is complete; but neither the consulting or stationary engineer can do justice to the owner of the plant unless **each** possess certain knowledge and experience required by the other. No consulting engineer can successfully design and install a steam power plant, unless he can **operate** the same should he be called upon to do so.

An engine, boiler, or dynamo may do the work required of it, but it may be so proportioned as to do it in a most uneconomical manner. For instance, while an engine may give the required power, its cylinders may be so small as to require an excessive amount of steam to run it; or a boiler may be so badly designed or so much too small for the steam necessary to be generated, that an **abnormal** amount of coal must be burned in order to generate the steam required.

Where a consulting engineer is not employed, it is usual for the owner of the plant to advertise for bids, and accept the lowest bid irrespective of the quality offered. No greater mistake can be made by the owner of any plant, for experience has shown that the **cheapest** machinery in the end is the most **costly.**

The chief requirement for the proper designing and construction of a plant is a good consulting engineer; and the largest return that the owner will receive from the capital invested in a plant, will be found to be in the



Section of the Crane Globe Valve.
Fig. 62.

great saving in the **economical operation** of the plant by a **good stationary engineer.**

QUESTIONS AND ANSWERS.

Q. What three things are necessary for proper boiler settings?

A. (1) A firm support for the boiler shell; (2) proper arranged space for furnace and ash pit; (3) a protective covering that will prevent the loss of heat by radiation from the boiler as far as possible.

Q. Why should a long cylindrical boiler be supported from three points?

A. Because the lower part of the shell expands more than the upper, which will cause the shell to sag in the middle, causing the middle support to take most of the load.

Q. When horizontal tubular boilers are supported by lugs resting on the side walls, how is any trouble from expansion and contraction of the boiler avoided?

A. By putting **rollers** under the rear lugs, thus permitting the rear end of the boiler to move horizontally.

Q. How much of the boiler should **never** be exposed to the fire or heated gases?

A. No part of the shell or tubes not completely covered with water.

Q. What is the object of laying the fire brick of a boiler with rows of **headers** at short intervals?

A. So that repairs can be made without tearing down the whole wall.

Q. How is the foundation for a boiler usually prepared?

A. By laying a bed of concrete upon which a wall of stone is laid in cement.

Q. Does the settings of water tube boilers differ from the settings of horizontal tubular boilers?

A Jenkins Globe Valve.
Fig. 63.

A. No, not essentially. The settings of water tube boilers vary only in the baffling of the gases, and the tiling required to conduct these gases in such a way as to keep them in **contact** with the tubes.

Q. Do all boilers require settings?

A. No. Self contained boilers require no settings.

Q. What is the best valve to use on the blow-off pipe?

A. A plug cock packed with asbestos.

Q. How should a globe valve always close?

A. It should always close **against** the pressure.

Q. What advantage has a gate valve over a globe valve?

A. The fluid or gas can flow through a gate valve with less resistance than through a globe valve.

Q. What is a check valve?

A. It is a valve so constructed that a fluid or gas can flow through it only in **one** direction.

Q. Why is it necessary to pack valves?

A. To prevent their leaking.

Q. What is an angle valve?

A. It is a valve which forms part of an angle.

Q. What is a throttle valve?

A. It is a valve used to admit steam to the engine so as to regulate its speed. To throttle means to choke, hence it is used to throttle the steam.

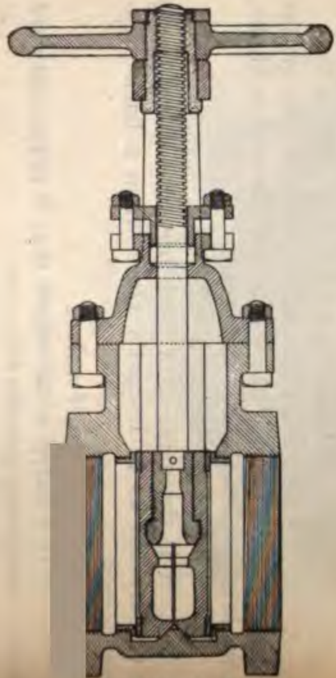
Q. What is a check valve?

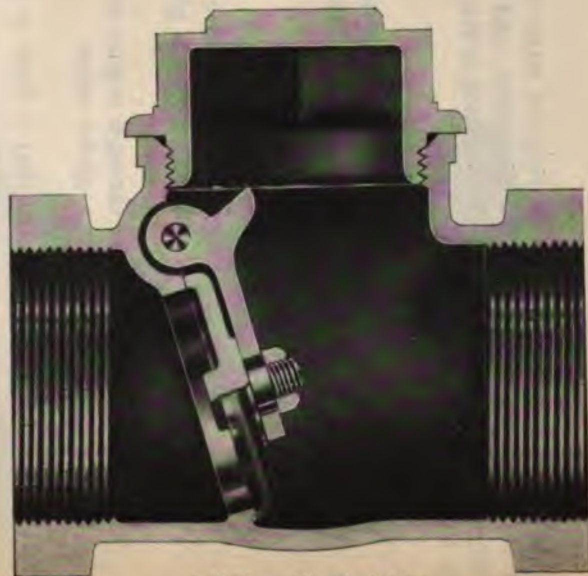
A. It is the same as a back pressure valve, being so constructed as to instantly close when a back pressure occurs.

Q. What is a relief valve?

A. It is a valve so arranged that it opens outward when a dangerous pressure occurs.

Q. What is a reducing valve?





A Swing Check Valve.
Fig. 65.

A. A valve to supply steam at less than boiler pressure.

Q. What is meant by a double seat or double beat valve?

A. It is a valve which presents two outlets for the steam or water.

Q. How should all steam valves be connected?

A. In such a manner that the valve closes against the constant steam pressure.

Q. Of what material are pipes used in a steam lant made?

A. They are now mostly made of wrought iron.

Q. What advantage has wrought iron over cast on for steam pipe?

A. It is stronger and lighter.

Q. Of what are pipe fittings mostly made?

A. Cast iron, malleable iron and steel.

Q. Of what should all pipe fittings for large pipe in igh pressure steam plants be made?

A. Of steel.

Q. Should cast iron fittings be used where they will e exposed to the fire or hot gases?

A. No, steel fittings alone should be used.

Q. How is the size of gas, or the ordinary black ipe usually designated?

A. By its internal diameter.

Q. Are boiler tubes designated in the same way?

A. No, their size is computed from the external liameter.

Q. Why is this distinction made?

A. Because boiler tubes are made much more accurate as to size than ordinary black pipe, the outside surface being made smooth, which is not the case with pipe.

Q. What is meant by the **settings** of a boiler

A. The foundation, the means of supportin boiler and the enclosing walls.

Q. How should the rear and side walls be b

A. Always **double**, with a 2 inch air space be them.

Q. How thick should the outer walls be mad

A. Always 12 inches, both side and rear.

Q. How thick should the inner side walls be at the center line of the boiler?

A. At least 9 or 10 inches, depending on th of the boiler.

Q. Why should the inside wall always be with a **batter**?

A. It not only gives greater stability to the but it also allows a better circulation of the gases.

Q. Where should this batter begin?

A. At the grates.

Q. How thick should the **inner** wall alwa made?

A. 12 inches.

Q. How thick should the front wall be mac

A. 9 inches.

Q. How many common and how many fire are required for a 72"x18' boiler with flush front

A. 24,000 common brick with 1,400 fire brick.

Q. What determines the **length** of the grates a boiler?

A. The grates should be made equal to t **ameter** of the boiler.

Q. How wide should the grates be made?

A. About 6 inches less than the diameter boiler.

Q. Is a bushing and a reducer used for the same purpose in pipe work?

A. Yes, but a reducer makes a much nicer appearance.

Q. What are the main considerations in piping a steam plant?

A. (1) The size of the pipes; (2) the arrangement and construction of the pipes; (3) the method of providing for expansion; (4) proper drainage.

Q. How are steam pipes generally proportioned?

A. So as to permit a velocity of 6,000 feet per minute of flow of steam in pipes carrying **live** steam, and 4,000 feet per minute in **exhaust** pipes.

Q. How is provision made for the expansion and contraction of pipe?

A. By the use of expansion joints, or simply bends in the pipes.

Q. How much is the expansion per 100 feet of length in steam pipes?

A. About 1½ inches per 100 feet.

Q. How are expansion joints generally constructed?

A. They are simply slip joints, and their usual construction is shown in Fig. 67.

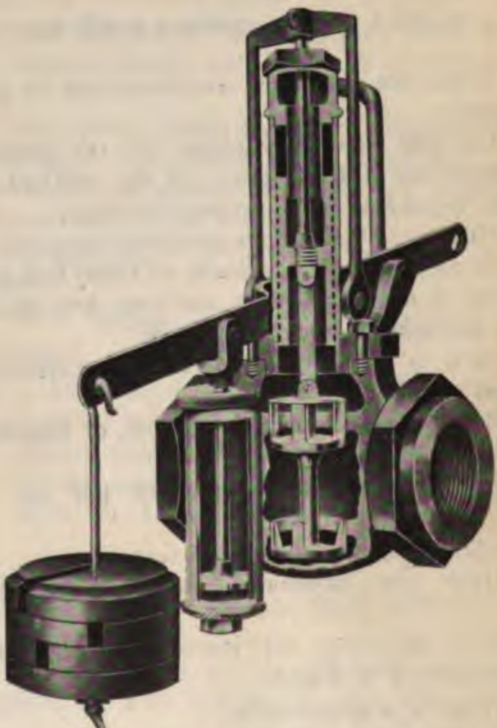
Q. What is a goose-neck?

A. It is simply a curve or bend in a pipe as shown in Fig. 68. The curved form enables it to take up all the expansion or contraction not only of the steam pipe, but also its own expansion or contraction.

Q. How should the curve or bend always be placed?

A. Upwards, in order that no water may collect in the bend.

Q. How should *all steam pipes* be arranged?



Sectional View of a Reducing Valve.
Fig. 66.

A. So that no pockets or angles are formed in which water may collect.

Q. What is a "water hammer?"

A. It is the steam coming in contact with the water which collects in the pipe, producing a noise like the blow of a hammer.

Q. Is the pressure produced by water hammer considered dangerous?

A. Yes, but experience has shown that it is not capable of producing the amount of damage generally believed.

Q. Should a consulting engineer be a good stationary engineer?

A. Yes, if he expects to design or install steam power plants.

Q. Should he be competent to operate such a plant?

A. Yes, in order to design such a plant so that it can be successfully operated by another.

Q. Should a stationary engineer be able to design and install a steam plant?

A. Yes, for he cannot successfully operate it unless he fully understands every piece of machinery in his charge, and how it can be most economically operated.

Q. How do you determine the **area** of pipe?

A. Multiply the square of the internal diameter by .7854.

Q. How do you determine the **size** of pipe required for a given size cylinder?

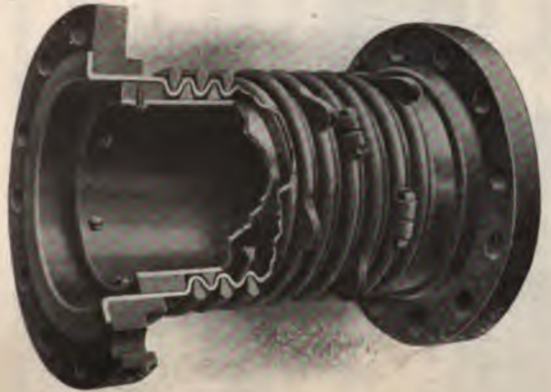
A. Multiply the cross-sectional area of the cylinder by the piston speed in feet per minute, and divide by 6,000.

Q. What is the highest **velocity** allowed for the flow of steam through pipe?

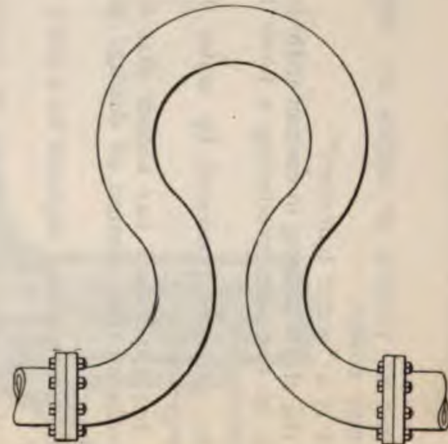
A. Not over 6,000 feet per minute.

Q. How do you determine the **capacity** in horse power for a given size of pipe?

A. Multiply the square of the *diameter* by 6.



Expansion Joint.
Fig. 67.



A Gooseneck.
Fig. 68.

STANDARD DIMENSIONS OF WROUGHT IRON AND STEEL STEAM, GAS AND WATER PIPE

Diameter			Nominal Thickness	Circumference		Transverse Areas			Length of Pipe per Square Foot of		Length of Pipe Containing one Cubic Foot	Nominal Weight per Foot	Number of Threads per Inch of Screw
Nominal Internal	Actual External Diameter	Approximate Internal Diameter		External	Internal	External	Internal	Metal	External Surface	Internal Surface			
Inch	Inches.	Inches.	Inches	Inches.	Inches.	Sq. Inch.	Sq. Inch.	Sq. Inch.	Feet.	Feet.	Feet.	Pounds.	
1/8	.405	.27	.068	1.272	.848	.129	.0573	.0717	9.44	14.15	2513.	.241	27
1/4	.54	.364	.088	1.696	1.144	.229	.1041	.1240	7.075	10.49	1383.3	.42	18
3/8	.675	.494	.091	2.121	1.552	.358	.1917	.1663	5.657	7.73	751.2	.559	18
1/2	.84	.623	.109	2.639	1.957	.554	.3048	.2492	4.547	6.13	472.4	.837	14
3/4	1.05	.824	.113	3.299	2.589	.866	.5333	.3327	3.637	4.635	270.	1.115	14
1	1.315	1.048	.134	4.131	3.292	1.358	.8626	.4954	2.904	3.645	166.9	1.668	11½
1¼	1.66	1.38	.14	5.215	4.335	2.164	1.496	.668	2.301	2.768	96.25	2.244	11½
1½	1.9	1.611	.145	5.969	5.061	2.835	2.038	.797	2.01	2.371	70.66	2.678	11½
2	2.375	2.067	.154	7.461	6.494	4.43	3.356	1.074	1.608	1.848	42.91	3.609	11½
2½	2.875	2.468	.204	9.032	7.753	6.492	4.784	1.708	1.328	1.547	30.1	5.739	8
3	3.5	3.067	.217	10.996	9.636	9.621	7.388	2.243	1.091	1.245	19.5	7.536	8
3½	4.	3.548	.226	12.566	11.146	12.566	9.887	2.679	.955	1.077	14.57	9.001	8
4	4.5	4.026	.237	14.137	12.648	15.904	12.73	3.174	.849	.940	11.31	10.665	8
4½	5.	4.508	.246	15.708	14.162	19.635	15.961	3.674	.764	.848	9.02	12.49	8
5	5.563	5.045	.259	17.477	15.849	24.306	19.99	4.316	.687	.757	7.2	14.502	8
6	6.625	6.065	.28	20.813	19.054	34.472	28.888	5.584	.577	.63	4.98	18.762	8
7	7.625	7.023	.301	23.955	22.063	45.664	38.738	6.926	.501	.544	3.72	23.271	8
8	8.625	7.982	.322	27.096	25.076	58.426	50.04	8.386	.443	.478	2.88	28.177	8
9	9.625	8.937	.344	30.238	28.076	72.76	62.73	10.03	.397	.427	2.29	33.701	8
10	10.75	10.019	.366	33.772	31.477	90.763	78.839	11.924	.355	.382	1.82	40.065	8
11	11.75	11.	....	36.914	34.558	108.434	95.033	13.401	.325	.347	1.51	45.028	8
12	12.75	12.	....	40.055	37.7	127.677	113.098	14.579	.299	.319	1.27	48.985	8

Table No. 8.

CHAPTER V.

BOILER ACCESSORIES.

Boiler Attachments.—The principal attachment t any boiler is the **furnace,** which varies in shapes and siz with the type of boiler and the kind of fuel to be burned The furnace consists of the fire and ash doors, grat bars, bridge wall and ash pit. The principal require ments of all properly constructed furnaces is a uniforn and abundant air supply to the under side of the grate so as to insure **complete combustion.**

In order to accomplish this there must be ample air space above the fire to permit of all the gases to be en-tirely consumed before leaving the furnace. Should it not be possible to have sufficient space between the grat and the shell of the boiler, then a combustion chambe must be used in which the combustion can be completed To insure complete combustion, most all furnaces ar provided with a combustion chamber.

Furnaces are designated either as **straight draft** o **down draft** furnaces, according to the direction taken b the draft, the majority of furnaces being straight draf furnaces.

The **furnace door** is usually of cast iron, provide in the center with a circular draft plate through which air is admitted to the fire above the grates.

Steam Pressure Gauge.—In Fig. 69 is shown a sec-tional cut of the **Bourdon Pressure Gauge,** which is a gauge universally used. As has been previously ex-plained this gauge is constructed upon the principle that a flat tube, curved to almost a complete circle and close at one end, tends to become **straight** when subjected t internal pressure. One end of this tube being fixed, the

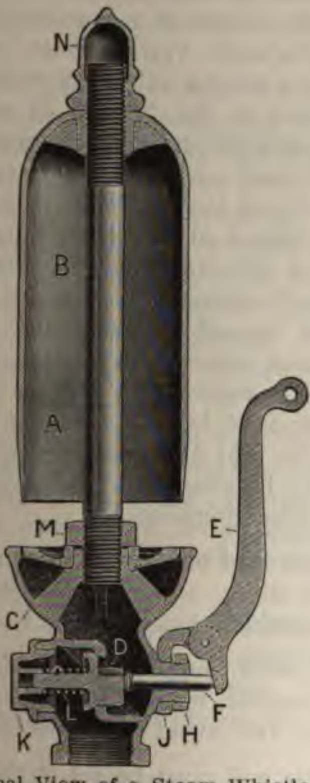
Sectional View of the Bourdon Steam Gauge.
Fig. 69.

internal pressure in straightening the tube, moves t other end. By means of levers, a curved rack and a pi ion, the motion of the **free end** is greatly multiplied a indicated by a needle which is attached to the pinic This needle is made to move over a dial which has be graduated, that is divided into spaces, so as to agr with the mercury column which is usually adopted the standard measurement of pressure, or with a star ard gauge. The back lash of the levers is taken up a hair spring. A **vacuum gauge** is similar in every spect to the above described pressure gauge with a s gle exception that the curved tube is turned in the **opp site** direction, so that the needle is made to move w a **decrease** of pressure, which indicates the decrease pressure below that of the atmosphere.

The Steam Whistle.—This boiler attachment is us for signaling purposes. There are two kinds, known the **bell whistle** and the **organ tube** whistle, the lat having now almost superceded the bell whistle on a count of the simplicity of its construction and superi tone. Great care should be taken to keep the whist pipe free from water, so that the whistle will sound soon as the steam is turned on. Fig. 70 shows a com mon form of steam whistle. The hollow base has narrow circular orifice that communicates with the stea pipe. The steam compresses the air contained in th bell of the whistle, thereby causing vibration to contin as long as the steam is permitted to flow, and the com munications of these vibrations to the surrounding a mosphere produces the sound.

In Fig. 70 is shown a sectional view of the Lunke heimer steam whistle.

Directions for Connecting.—To give best resul *whistles* should be placed as nearly as possible over t



Sectional View of a Steam Whistle.
Fig. 70.

boiler and above surrounding buildings, so that sound will not be obstructed. If they are so placed t there are a number of bends and off-sets in the conn ing pipes, or the whistle is a considerable distance fr the boiler, the whistle valve should be directly un the whistle and a second valve (an ordinary stop val should be placed at the bottom of the pipe. Me should be provided for draining the connecting pipes placing a small drain cock directly above the lower va If the whistle is not too far from the boiler, the whi valve can be placed at the bottom of the connec pipes instead of directly under the whistle. When erating a whistle connected as above, the drain c should be first opened to allow any condensed wa (which may have accumulated in the pipes) to esca If a stop valve is used at the bottom of the pipe, op same a moment or so before operating the whistle val so as to heat the pipe and get dry steam to the whist They should not be attached to steam pipes used to su ply steam for other purposes.

Use as little lead or pipe joint grease as possible i connecting the pipes, and blow out thoroughly befor connecting the whistle.

Take the steam supply directly from the dome o the boiler, if possible, so that it will be dry and of maxi mum pressure, and avoid all unnecessary elbows, etc

The whistle bell must be set at the proper distance from the slot in the top of the base to suit the steam pressure. To regulate this: loosen the acorn-shaped lock nut on top of the bell and screw the bell down o up until it blows satisfactorily. For higher pressure screw the bell up and for lower, down. When properly adjusted be sure to again tighten the lock nut.

Feed-Water Heaters.—The advantage of introducing the feed-water into the boiler at a high temperature is the saving in the **fuel,** and the avoidance of the **strains** produced upon the boiler by the introduction of cold feed-water.

Economy.—The great economy of using the waste heat in exhaust steam for heating the feed-water can be clearly seen from the following calculation:

When the feed-water enters the boiler at 60 degrees Fahrenheit, and the boiler is furnishing steam at 100 pounds gauge pressure then the number of heat units required to change a pound of water at 60 degrees into steam at 100 pounds pressure is equal to 1,157 B. T. U., as can be seen from the Steam Tables. Therefore, the number of heat units gained by utilizing the exhaust steam for heating the feed water is $210 - 60 = 150$ B. T. U., which is a gain of about 12 per cent.

In using the steam tables always be careful to convert **gauge** pressure into **absolute** by adding 15 pounds, which is about the pressure of the atmosphere. Hence, the absolute pressure of 100 pounds gauge pressure is 115 pounds.

Classification of Feed-Water Heaters.—There are two separate and distinct classes of feed-water heaters, both of which classes are in general use. The first class is known as **closed heaters,** and the second class as **open heaters.**

Closed Heater.—In this class of heaters the feed-water is not exposed to the atmosphere, but is subjected to the temperature of the steam by bringing the metal tubes through which the feed-water is pumped, in contact with the steam. In this form of heater the water in passing through the tubes extracts the heat from the exhaust steam contained in the shell of the heater. The

feed-water is therefore pumped **through** the heater the boiler, the heater being **between** the pump and boiler. This permits the pump to handle the water c which is a decided advantage, as it is much easier pump cold water than hot water.

This form of heater is called a **closed** heater, s the water to be heated is confined in tubes or pipes. T exhaust steam does not come into contact with water to be heated, but surrounds the tubes or pipes the heater, and in this way heating the water befc its entrance into the boiler. In the closed type of hea the water is usually caused to circulate through tub arranged in different ways, while the exhaust steam e velopes the tubes from end to end in passing through t heater from the inlet to the outlet of same. Occasio ally, this form of heater is constructed with the wat outside and the steam inside the tubes, but the form method of heating gives a much more rapid circulatio and is therefore much more efficient.

Open Heater.—This class of heater can be sub divided into two sub-classes, being known as **direct con tact open heaters,** and **coil heaters.** In the first sub class, the exhaust steam comes into **direct contact** wit the water, which readily absorbs the heat of the steam

In a **coil heater** the water does not come into co tact with the exhaust steam, but it is heated by the e haust steam which passes through coils of pipe su merged in a suitable vessel or heater containing t water. This vessel or heater is open at the top, th permitting the water to be exposed to the atmospher This form of heater is rarely used, it being neither ef cient nor economical.

In the **open direct contact heater,** which is the mos generally used form of heater, the exhaust steam an

feed-water are brought directly into contact and made to **mix**, thereby causing most of the steam to be condensed and imparting its heat to the water. This form of heater must always be placed on the **suction** side of the feed pipe, and hence the **pump** is between it and the boiler.

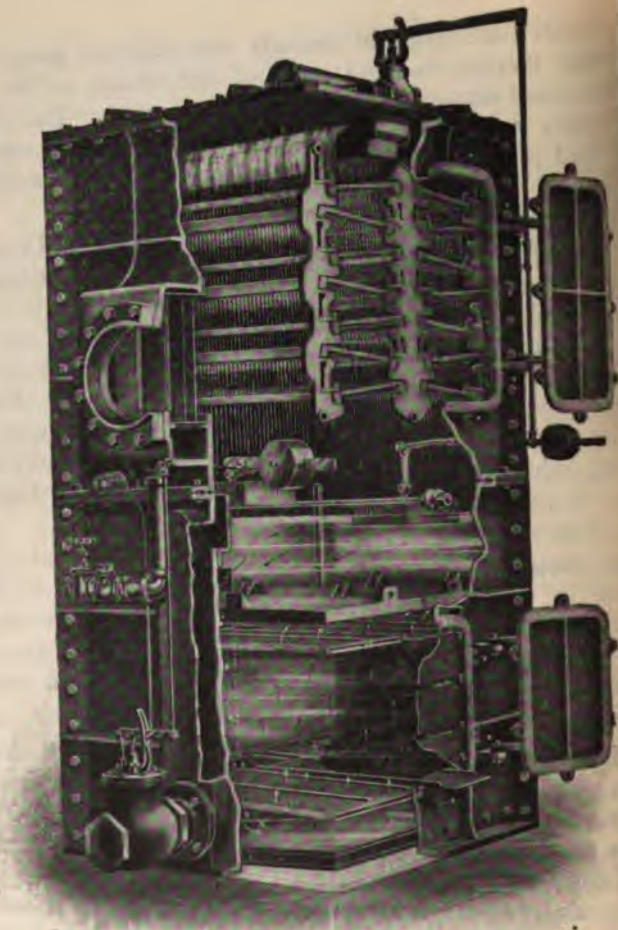
Disadvantages.—As the exhaust steam and water are brought together, all the oil or grease carried over from the engine in the exhaust steam will mingle with the heated water, necessitating some mechanical means to separate the two, so that the water fed to the boiler will be free from it. This is usually done by **filtration**, or by an oil **separator.** As the pump is between the heater and the boiler it requires the pump to handle hot water, which requires the heater to be placed **higher** than the pump.

With this form of heater a temperature of 210 degrees should be maintained, which in addition to the saving in fuel, is also desirable as at this temperature most of the scale forming substances, with the exception of the sulphates, are precipitated, so that this form of heater also acts as a **water purifier.**

Object.—The object of the feed-water heater is to reclaim as far as possible all of the heat in the waste steam, and to also act as a feed-water purifier. The feed-water heater utilizes the **waste steam,** while the **waste gases** are utilized by an **economizer.**

Location.—The feed-water heater should be placed at any convenient point in the exhaust steam line, although it is better to locate it as **near** the engine as practical.

In Fig. 71 is shown a common form of a direct contact open heater. Table No. 9 shows the great economy from the use of feed-water heaters.



Sectional View of the Webster.
Exhaust Steam Feed-Water Heater and Purifier.
Fig. 71.

Feed-Water Purifier.—As most of the scale-forming substances in water become insoluable in precipitate when the water which contains them in solution is heated to a sufficiently high temperature, a feed-water purifier is simply an apparatus in which either live or exhaust steam is used to heat the feed-water for this purpose. In **live steam purifiers** the water is heated by the live steam at full boiler pressure. In order to raise the temperature of the water to 290 degrees Fahrenheit required to precipitate the principal scale-making element, sulphate of lime, the heater is subjected to the full boiler pressure, the water being pumped into it, and it then entering the boiler by gravity. A temperature of about 212 degrees Fahrenheit is necessary to precipitate the carbonate of lime.

This type of heater is called a live steam purifier to distinguish it from those in which the water is heated at atmospheric pressure, or a pressure slightly above it. A live steam feed-water purifier cannot be as economical as a feed-water heater in which the exhaust steam alone is used, as where the exhaust steam is used for heating the water, it is then taken from a source of **waste.** On the contrary when the **live** steam is used for this purpose, the steam is taken from the boiler, and there can be no direct saving in fuel, but only an **indirect** saving by the prevention of accumulation of scale in the boiler, which is always a source of waste of fuel.

In Fig. 101 is illustrated a common form of a live steam feed-water heater and purifier.

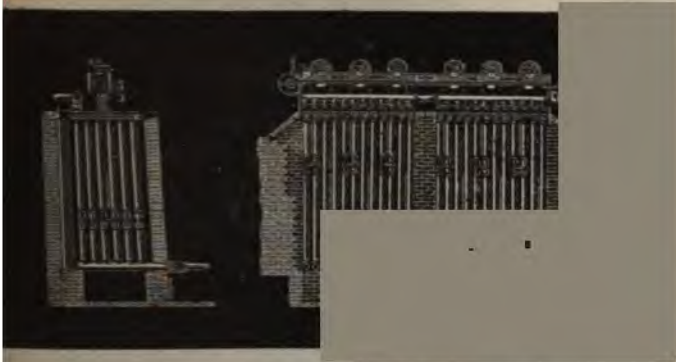
Economizer.—The object of the economizer is to reclaim as far as possible the heat in the **gases** escaping into the chimney, and to use this heat to raise the temperature of the feed-water. The temperature of the gases on entering the chimney is usually from 400 to

600 degrees Fahrenheit. By lowering this temperatur to 250 to 300 degrees, quite a saving of fuel is obtaine The **draft** of the chimney, however, depends upon th **temperature** of these gases, and this loss of temperatur must be made up by increasing the **height** of the chim ney in order to maintain the draft.

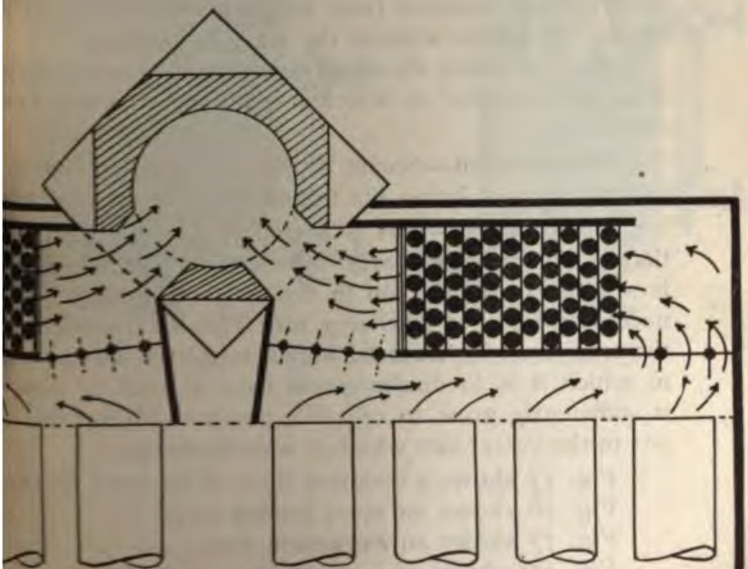
Fig. 72 shows the position of an economizer wit respect to the boiler and chimney. As can be seen, it i placed directly in the flue. The hot gases from th boiler pass through the row of tubes on their way to th chimney, thus heating the feed-water which is made t circulate through these tubes. In this way the feed-water may be heated to as high as 350 degrees Fahren-heit, and the temperature of the gases reduced to about 300 degrees Fahrenheit.

Steam and Oil Separators.—A separator is an apparatus designed to remove the water, oil, dirt and other impurities from a current of steam flowing through a pipe. When it is intended to separate the steam from the water, the separator is placed on the main pipe leading from the boiler to the engine, and as **close** as possible to the engine. When it is used to remove the grease and dirt from **exhaust steam** before using as feed-water for the boiler, the separator is placed in the exhaust pipe leading from the engine to the condenser, or heater.

Classification.—Steam separators are divided into two general classes, viz.: (1) **Baffle plate separators**, (2) **Centrifugal separators.** In the first class, the steam comes in contact with the baffle plates placed at right angles to its direction of flow, thus sharply changing the direction of flow of steam. In a **centrifugal separator** the steam is given a whirling motion in flowing through the apparatus, and by this whirling motion the *water is* separated from the steam.



An Economizer, Showing Its Location.
Fig. 72.



Sectional View of Economizer.
Fig. 72.

Action.—The principle of all separators depends on **inertia.** Since water or oil is much heavier than steam, their inertia is much greater than that of the steam. Consequently, when the current of steam comes in contact with the baffle plate, the steam changes its direction with ease, but the heavier particles of water or oil, by reason of their inertia are dashed against the baffle plate, thus separating them from the steam which flows on to the engine.

Fig. 73 illustrates a common form of a horizontal and vertical centrifugal separator, which is known as the Detroit Separator. In Fig. 78 is shown the separator connected **direct** to the engine.

Steam Trap.—This is an appliance for **removing** the water of condensation from steam pipes, separators, and similar apparatus without the waste of steam.

Fig. 74 shows the usual connection between a steam trap and separator, in which 1 is the separator and 2 the steam trap.

Classification.—Steam traps are divided into two general classes, being viz.: **open traps** and **closed traps.**

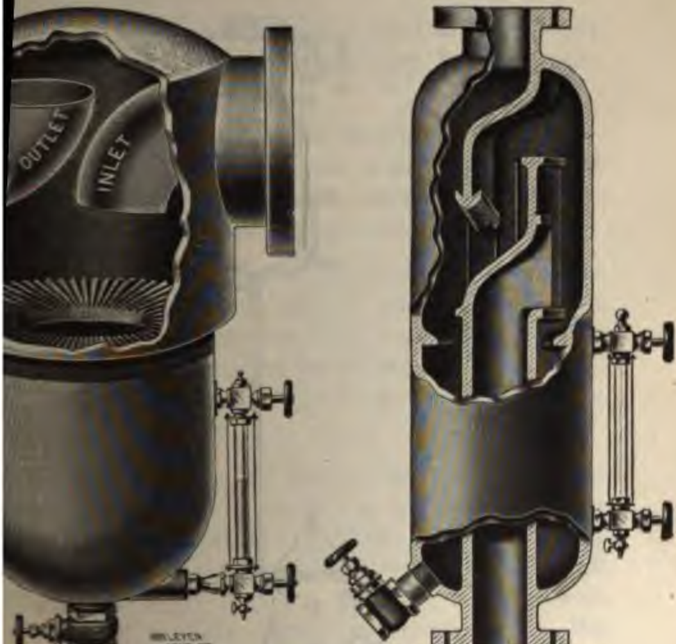
Open Traps.—This is a trap that is so constructed that it can only discharge into a vessel in which there is a **lower pressure** than in the trap. Should it become necessary for it to discharge into a higher pressure, then the trap must be **elevated** high enough above the vessel in which it is to discharge, to have a head of water in it sufficiently great to create a pressure higher than exists in the vessel into which it is to discharge.

Fig. 75 shows a common form of an open **float** trap.

Fig. 76 shows an open **bucket** trap.

Fig. 77 shows an **expansion** trap.

Fig. 111 shows an **open trap** so placed as to return the condensation direct into the boiler.



tional View of a Horizontal and Vertical Centrifugal
Separator.
Fig. 73.

A Steam Trap Connected to Separator.
Fig. 74.

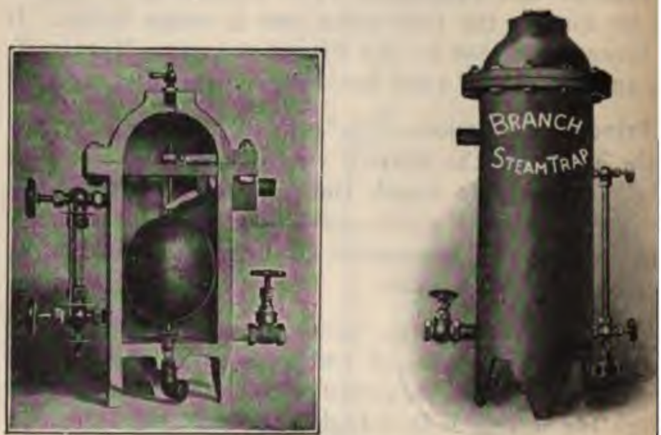
Closed Trap.—Such a trap is so constructed as to be able to discharge the water of condensation from a system in which there is low pressure, into a vessel in which there is a high pressure.

This form of trap is not generally used, it being more economical to use the cheaper open trap for this purpose.

Injector and Inspirator.—The injector is an apparatus for forcing the feed-water into a steam boiler. It was invented in 1858 by the French scientist, Henri Giffard, and since that time has been universally used.

Principle of Action.—The velocity of the steam carries the air inside the injector with it, and thus creates a partial vacuum into which the feed water flows. The steam then imparts a portion of its velocity to this water, giving it sufficient momentum to force open the check valves and enter the boiler.

Essential Parts.—Fig. 79 shows the essential parts of an injector by means of which the injector performs its work. Steam is admitted through (a) and flows through the nozzle with a high velocity, passes through the combining tube (d) and out through the overflow (e) and nozzle (g). This current of steam carries the air in the chamber (b) with it, thus forming a partial vacuum; the pressure of the atmosphere then forces the water from the supply into the chamber and into the combining tube (d). In (d) the steam and water are combined, with the result that the steam imparts a great deal of its velocity to the water and at the same time is condensed. This forms a jet of water that flows from the combining tube (d) with such a **high velocity** that it passes over the overflow (e) and into the discharge pipe (h), the energy in the water being great enough to



A Float Steam Trap.
Fig. 75.

overcome the pressure in the boiler. The water thus flows past the check valve (i) into the boiler.

The check valve is not a part of the injector itself, but it is a most essential part of the installation.

Steam Supply.—When the injector is working properly the feed-water is forced into the boiler in a steady unbroken jet, but should the feed-water be **too hot** to condense the steam used to operate the injector, then the steam owing to its lightness will not be forced into the boiler, but will flow out of the overflow.

Should the supply of steam be **too large**, then all of it will not condense in the combining tube and it will be discharged from the overflow nozzle. When the supply of steam is **too small**, its momentum is not then sufficient to carry it into the discharge pipe against the pressure in the boiler, and the water is discharged out of the overflow nozzle.

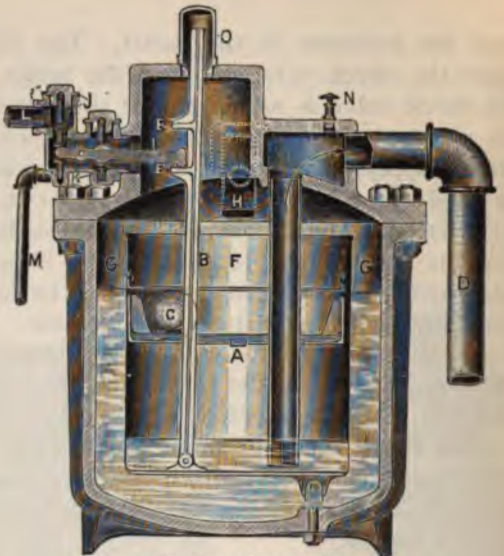
It is only necessary to watch the overflow nozzle in order to know when the injector is working properly.

Range of an Injector.—This term refers to the steam pressure at which an injector will start, and the steam pressure at which it ceases to work.

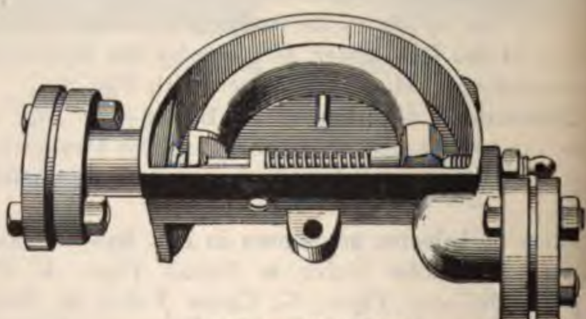
Table No. 10 shows the **range** of injectors, with temperature of the feed-water, as given by the International Correspondence Schools, together with Fig. 79.

Connections of Injector to Boiler.—In Fig. 80 is shown the proper way to connect up the Penberthy injector, which is a well known type of an automatic injector.

Parts of Injector as Shown in Fig. 80.—B, Body of Injector. D, Globe Valve in Steam Pipe. F, Check Valve in Delivery Pipe. G, Globe Valve in Delivery Pipe. H, Globe Valve in Suction Pipe. J, Water Supply taken from below Injector. K, Water Supply taken from Overhead Tank. L, Waste Pipe from Overflow.



A Bucket Steam Trap.
Fig. 76.



An Expansion Trap.
Fig. 77.

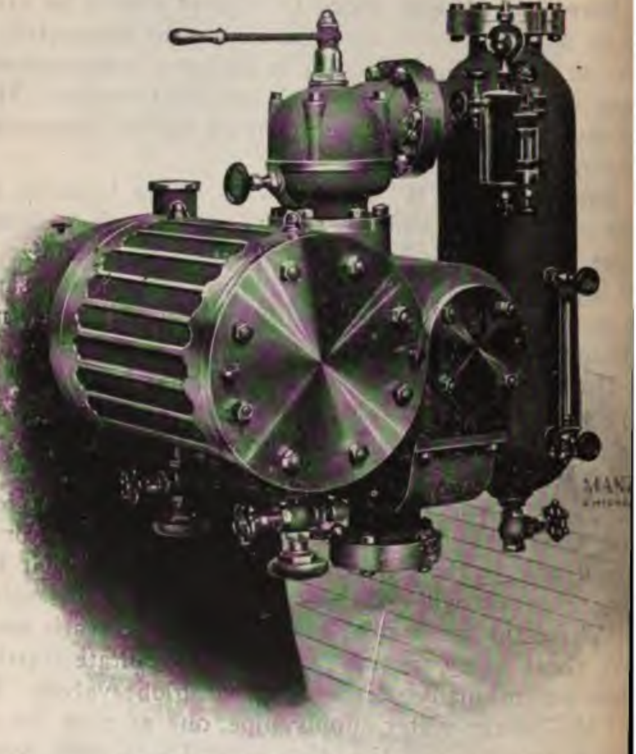
M, Second Globe Valve in Water Supply Pipe where an Overhead Tank is used or supply is taken from Water Works Pressure.

Direction.—Steam Pipe "D" should always be same size as injector connections, and must be connected to boiler at the highest possible point, and independently of any other pipe, in order to insure best results. This pipe must be blown out with steam before connecting injector.

Suction Pipe "H" must always be as large as injector connections, and where lift is over 10 feet, should be one or two sizes larger, reducing to injector size as near injector as possible, and having a globe valve same size as larger pipe. Be sure and put a **globe valve** (not straightway) in the water supply pipe.

On a Long Lift a foot valve should be placed on lower end of suction pipe. Without a foot valve, every time the injector is started the air must all be exhausted from the suction pipe before the water can reach the injector, and considerable steam is wasted. With a foot valve, the water is held in the pipe when injector is stopped and is there when starting again, so that the saving in steam will soon pay for the cost of this valve.

Where the water pressure is heavy, such as is usual where there is a city water works, to facilitate starting with low steam, many persons use two globe valves, "H" and "M," in the water supply pipe, one as near the injector as possible and the other several feet away, forming a "well" between the two. The far away valve "M" can then be used to reduce the pressure and the one near the injector for regulating the water supply. The same result can be obtained by using a water supply pipe and valve one size smaller than injector connections.



Steam Separator Connection to Engine.
Fig. 78.

The Delivery Pipe should be same size as injector connections, or larger if desired. There should be a check valve, "F," and also a globe valve, "G," in this pipe, the latter for use in case the former gets out of order.

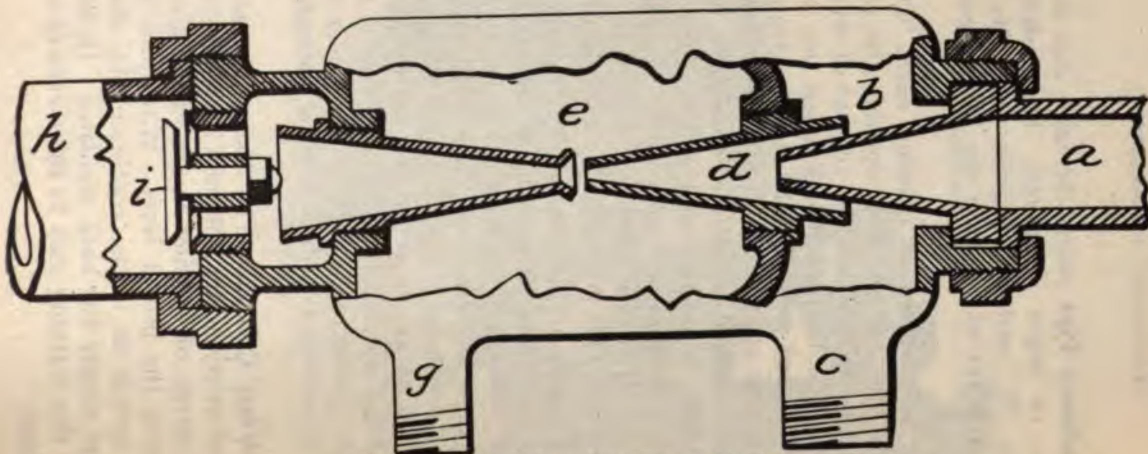
Injector is operated by opening valve "D" in the steam supply pipe full and then opening the valve "H" in water supply, with which the amount of water delivered to boiler can be regulated. When this valve has once been regulated properly, the steam valve only will need to be used to start and stop the injector, unless the steam pressure carried has altered to a great extent.

Inspirator.—An injector and an inspirator are the same, the term **inspirator** being merely a trade name adopted by the Hancock Inspirator Company for their make of injector. This inspirator is shown in Fig. 121.

Water Column.—This consists of a large hollow tube with its ends connected with the steam and water spaces of the boiler, and on which tube the gauge cock and water gauge is connected. The advantage of the use of the water column is the placing of the gauge cock and water glass so as not to be effected by the violent evolutions of the water within the boiler, as is the case when they are connected directly to the boiler head.

Fig. 97 illustrates a form of a **water column** in general use.

Safety Water Column.—The first and most important object of safety water columns is to give warning to those in charge of a boiler in case the water varies above or below the proper level. When this happens the whistle sounds an alarm, continuing to blow until the feed-water supply has been regulated. In the event of low water this warning may be the means of averting a boiler disaster.



Essential Parts of an Injector or Inspirator.
Fig. 79.

Its Economic Value.—The protection afforded is in itself sufficient reason for equipping every boiler with this device. But in addition there are several economic advantages to be gained from its use, all of which are the natural result of keeping the water steady at the proper level.

A Saving in Fuel.—When the water level is constantly changing there is bound to be great loss of heat and fuel. If the water is too high an unnecessary amount of heat is required, involving wasteful consumption of fuel. If it is too low it necessitates the sudden forcing in of a large quantity of water at a lower temperature to absorb the heat and reduce the steam pressure. Another waste of heat, fuel and money.

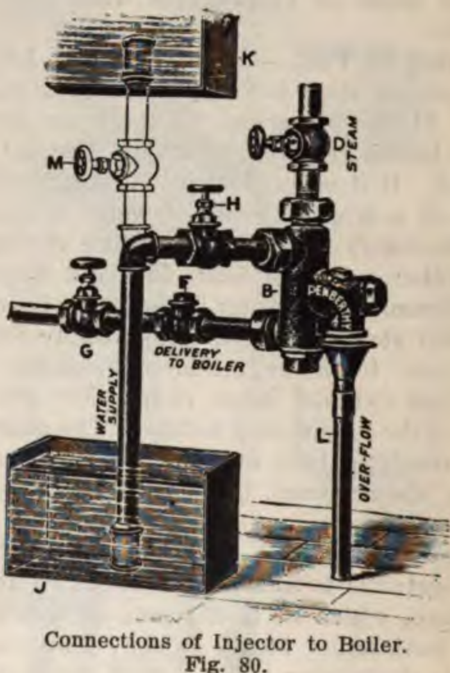
Dry Steam.—High water in the boiler is not only the cause of wet steam, but gives opportunity for water to be drawn over to the engine in considerable quantities. A blown out cylinder head, or possibly the complete wrecking of the engine may follow. The gain in engine efficiency resulting from steady steam pressure and the use of dry, elastic steam, is too well understood to need discussion.

Increased Durability of Boilers.—Another effect of unsteady water is to cause fluctuations of temperature and pressure, which in turn result in constant expansion and contraction of the boiler. This racking and straining is destructive to the life of the boiler and the source of frequent repair bills as well.

Fig. 97. shows a common form of a **safety water column.**

FURNACE ATTACHMENTS.

Grates.—The grates should not be larger than can be conveniently cleaned and fired. Two fire doors should be provided when they are more than 4 feet wide.



Connections of Injector to Boiler.
Fig. 80.

The grates are usually inclined slightly to the rear to aid in firing, and also to permit a freer access of the air.

Grate Bars.—They are usually made of **cast iron** and their shape and size depend on the character of furnace or fire box and the fuel to be burned on them.

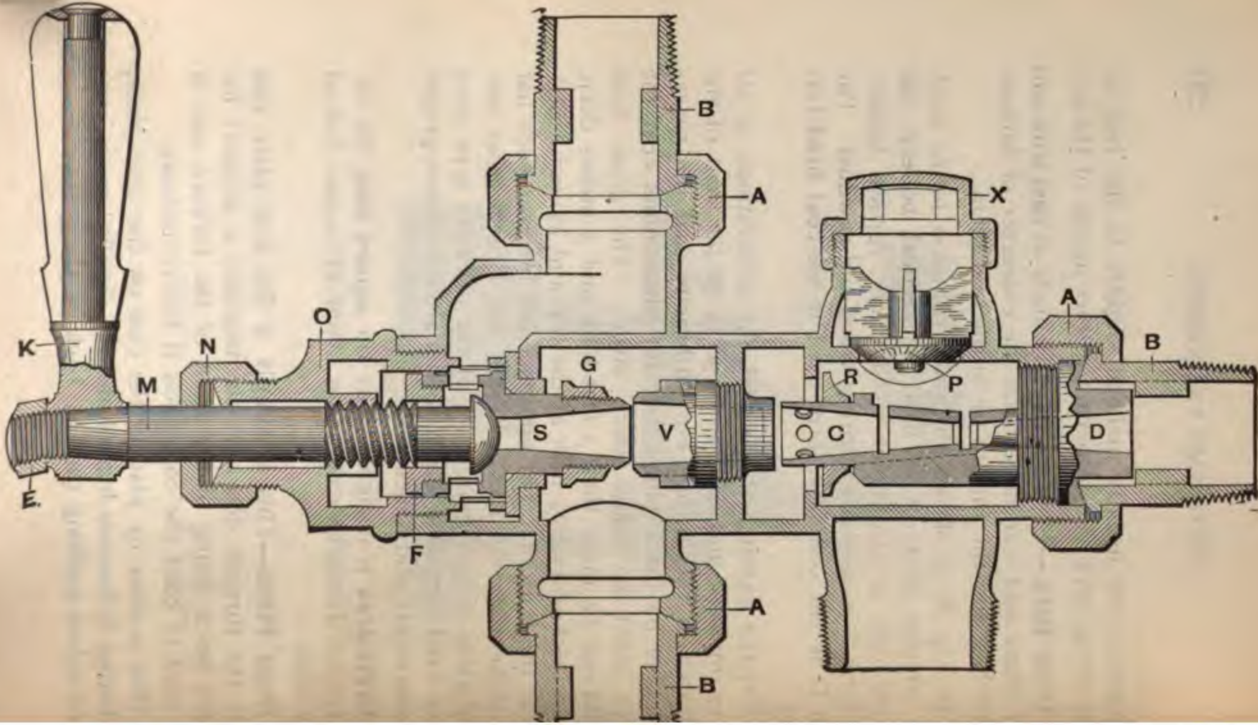
In Fig. 82 is shown the most common forms used. The circular grate A is used in **vertical boilers;** the herring-bone is also much used under vertical boilers. The form B is used for burning **wood** and **sawdust.** The form D is the ordinary form used in all **coal fired** furnaces.

For the burning of **fine coal,** the perforations, or air spaces, must be not over from 30 to 50 per cent of the total area of the grate. For **anthracite coal** the spaces must also be made small, but for **bituminous coal** the spaces must be made much larger. The grate bars should not be more than 3 feet long and 3 inches deep, with a thickness of ¾-inch at the top and ⅜-inch thickness at the bottom. The **air space** left between each bar should be about ½ inch. In Fig. 82, E is a cross sectional view of two grate bars of the ordinary type used in coal fired furnaces, which sectional view shows proper measurements and spacing.

Grate area is designated by the **square foot,** the ordinary size furnaces containing about 25 square feet of grate area.

Dead Plate.—This is simply a flat iron plate just inside the furnace door, which furnishes a support for the fire brick lining of the front of the furnace, and is also used to **coke** the coal upon it before burning.

This is done by placing the coal on the dead plate, and letting it become heated and the distilled gases consumed before pushing the coal back on the grate.


B
A
X
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Bridge.—This is a wall built at the back end of the ate, and forming the rear end of the furnace. The urpose of this bridge wall is to bring the flame and eated gases in **close contact** with the heating surface of he boiler. The distance between the bridge and the oiler shell should be from 6 to 10 inches according to he size of the furnace and the character of the fuel to e burned.

Damper.—This is an apparatus to keep the steam pressure **constant** by regulating the draft. The draft is regulated by controlling the volume of gases permitted to pass into the chimney. This in turn regulates the **intensity** of the fire and the **generation** of steam.

While there are a great variety of damper regulators, many of which are automatically operated by the pressure of the steam on a diaphragm, they are generally constructed upon the same principles. **Automatic damper** regulators are used mostly in **low pressure heating** plants. Fig. 126 is a cut of a **damper regulator** in general use.

Mechanical Stokers.—While shaking grates are designed to permit the cleaning of the fire without opening the fire doors, and to further facilitate the cleaning of same by not exposing the firemen to excessive heat, **mechanical stokers** were devised to save the labor of feeding furnaces by hand. There are a great many styles in use, the first mechanical stoker having been invented by James Watt.

One form in general use consists of longitudinal bars connected by links forming an endless chain. The coal is charged into a hopper and by it delivered at the front of the boiler on this endless chain. The moving of the grate from the front to the rear of the furnace,

moves the coal into the furnace, and then disposes of the ashes and clinkers when it reaches the back of the furnace.

Classification.—Mechanical stokers are divided into two general classes, viz.: **over-feed** and **under-feed.**

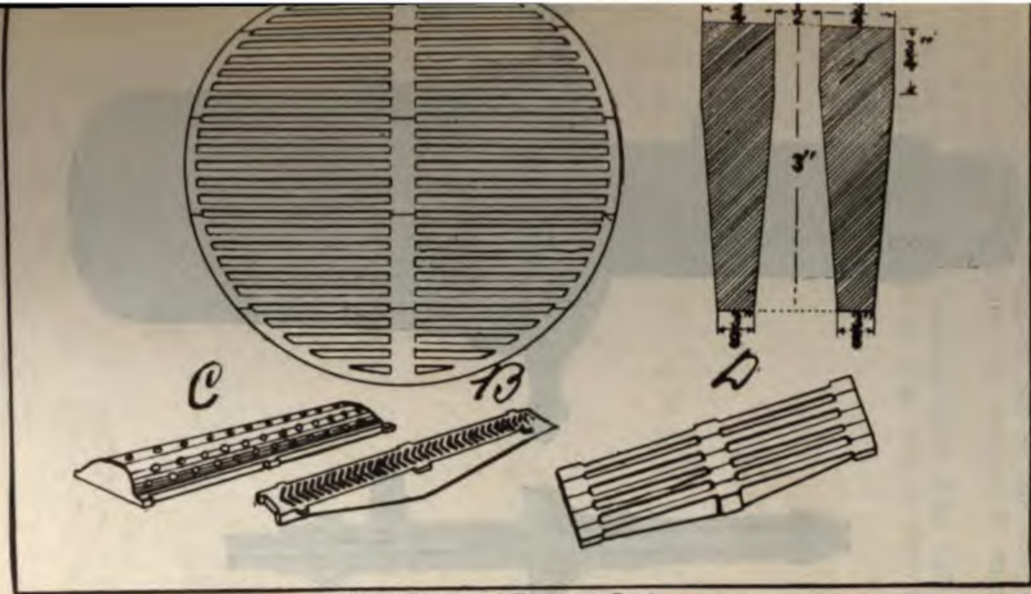
Over-Feed.—In this design of stoker the coal is fed **on** a coking plate, where the volatile matter is distilled off by the heat of the furnace and mixed with the proper amount of air. The coke remaining is then carried forward onto the grates, where it is burned.

Under-Feed.—In this design of stoker, the coal is forced by some mechanical device into a chamber under the mass of burning fuel in the furnace. The coke which is formed is pushed upwards by the fresh coal that is fed into the hopper, and burns above the coking chamber on suitable grates on which it falls.

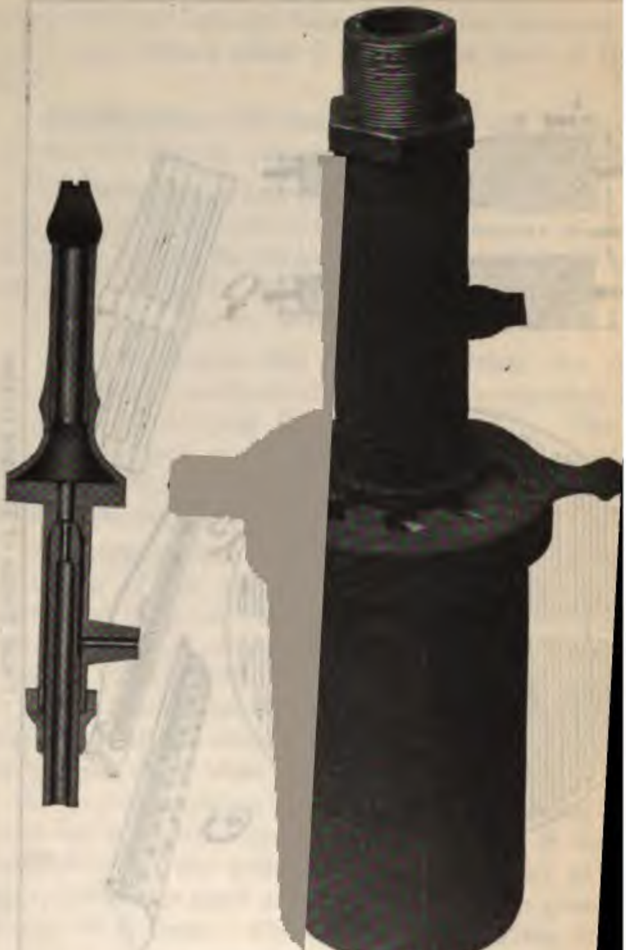
Advantages and Disadvantages.—There is little or no saving in the use of mechanical stokers in small **plants,** and so far as the **economy** is concerned but little saving in the use of automatic stokers over hand firing in large plants. The chief advantages obtained from the use of mechanical stokers is the **relief** on the firemen from much of the severe and difficult part of his work and the saving of **wear** and **tear** on the boiler.

With a mechanical stoker a constant opening of the fire doors is entirely avoided. No **cold** air is therefore admitted under the boilers to cause, not only great **injury** to the boiler itself and **waste** of fuel, but great hardship on the fireman. There is a further saving of **labor** as with a good mechanical stoker one man can do the work of several.

As more perfect combustion can be obtained with mechanical stokers than with hand firing, owing to the

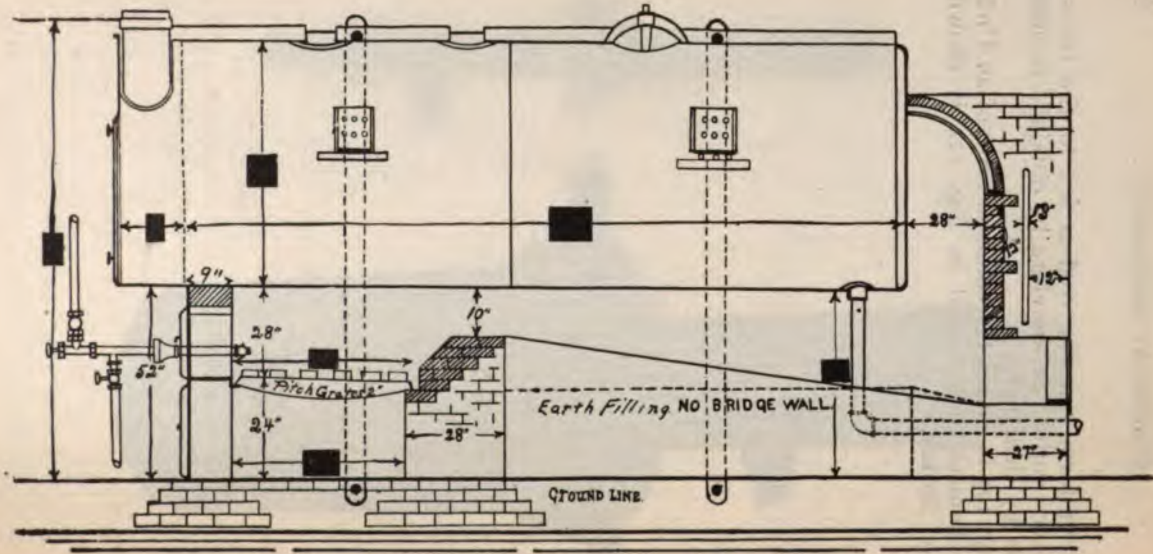


Usual Forms of Furnace Grates.
Fig. 82.

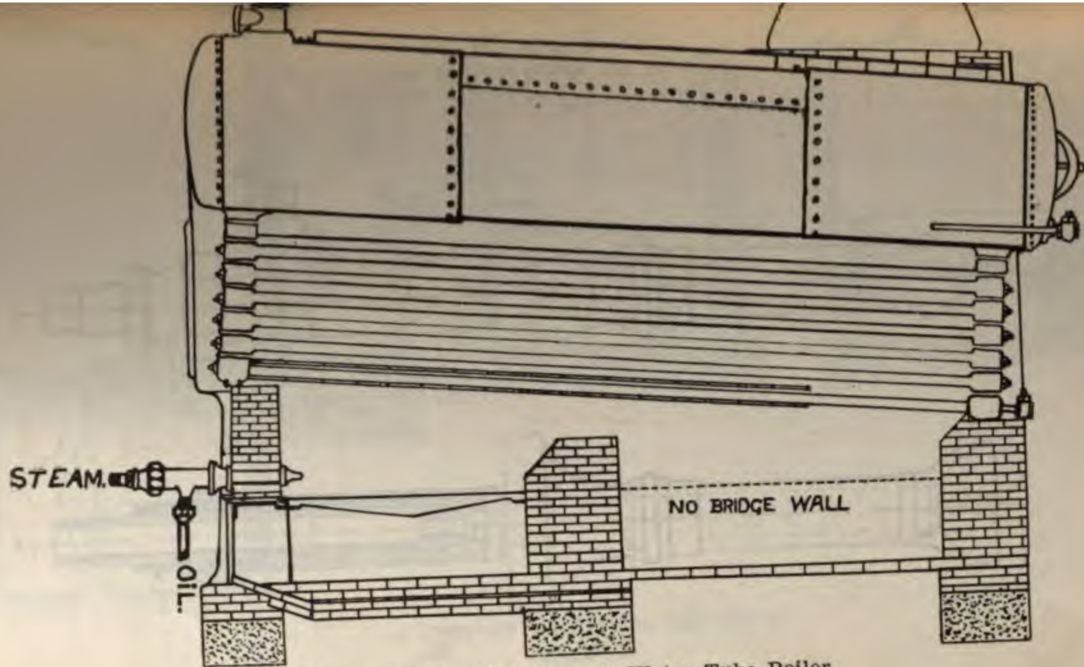


even and uniform rate the coal is fed to the furnace, much better results can therefore be obtained in smoke prevention by their use.

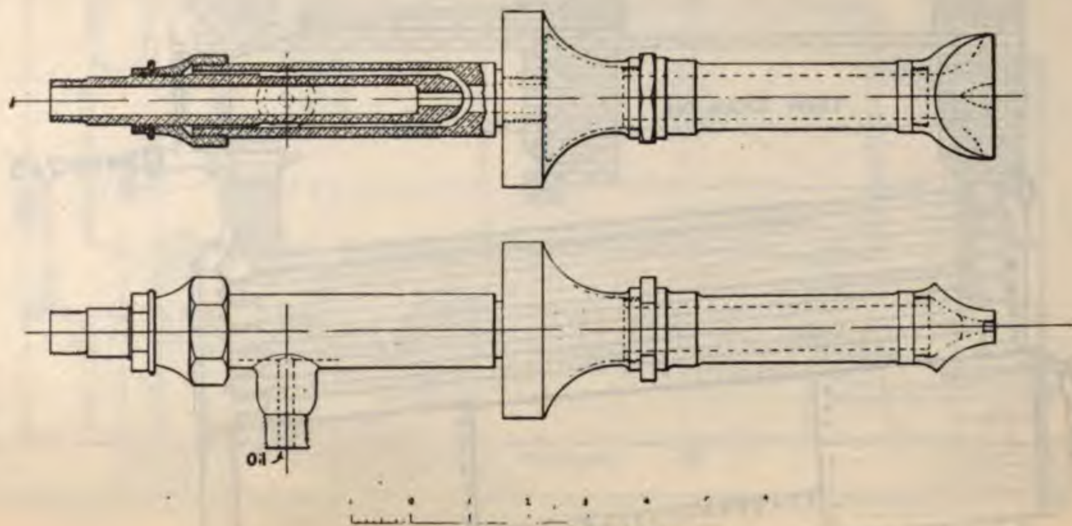
In Fig. 125 is shown the common form of an Under-Feed Mechanical Stoker, and in Fig. 124 is shown a Front-Feed Stoker.



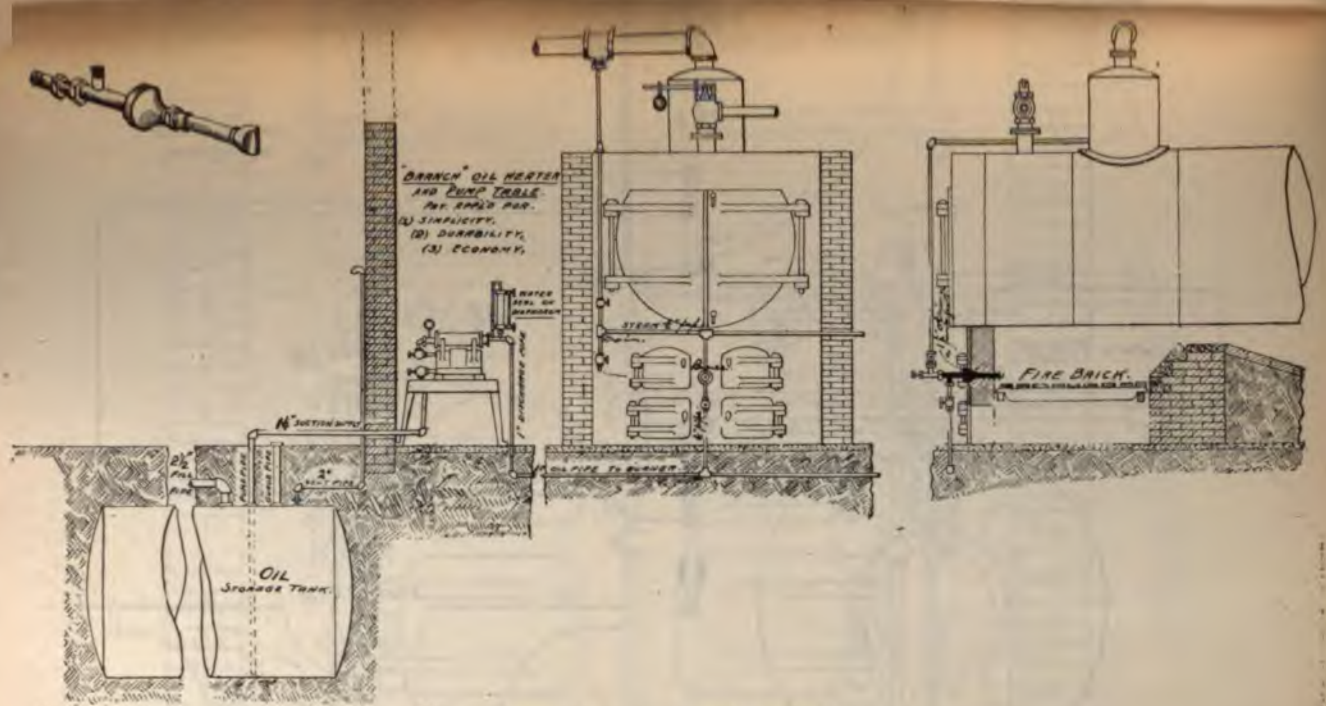
Crude Oil Burner Installed. (Burner much enlarged in length.)
Fig. 84.



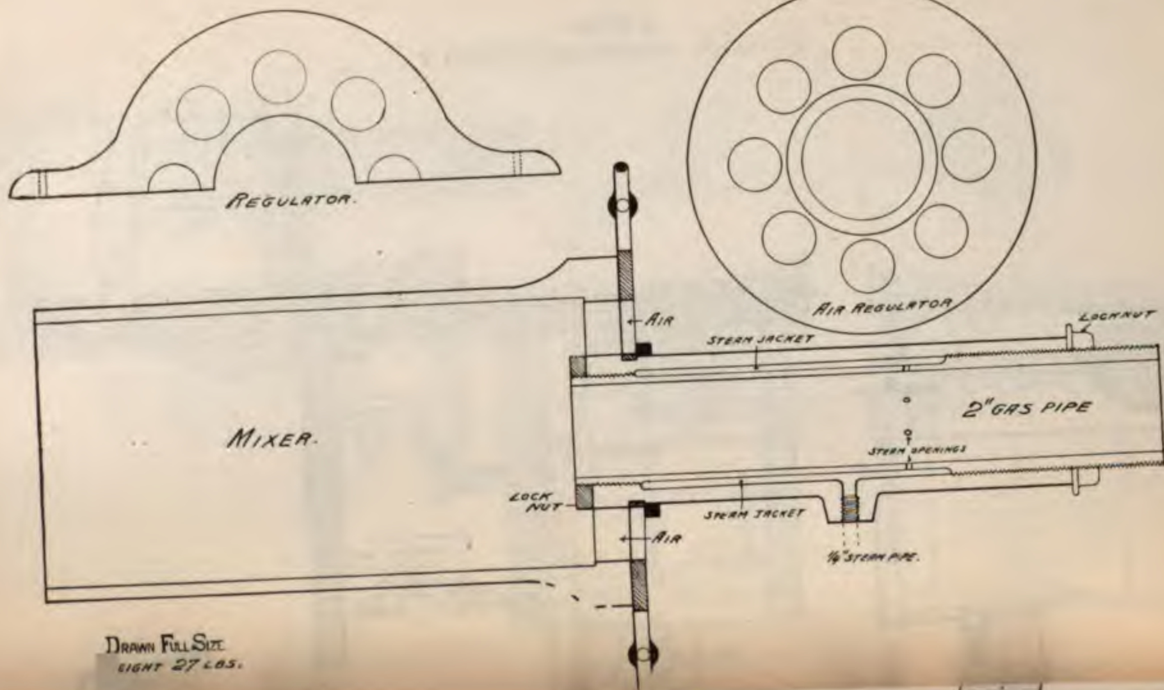
Oil Burner Installed Under a Water Tube Boiler.
Fig. 84-1.

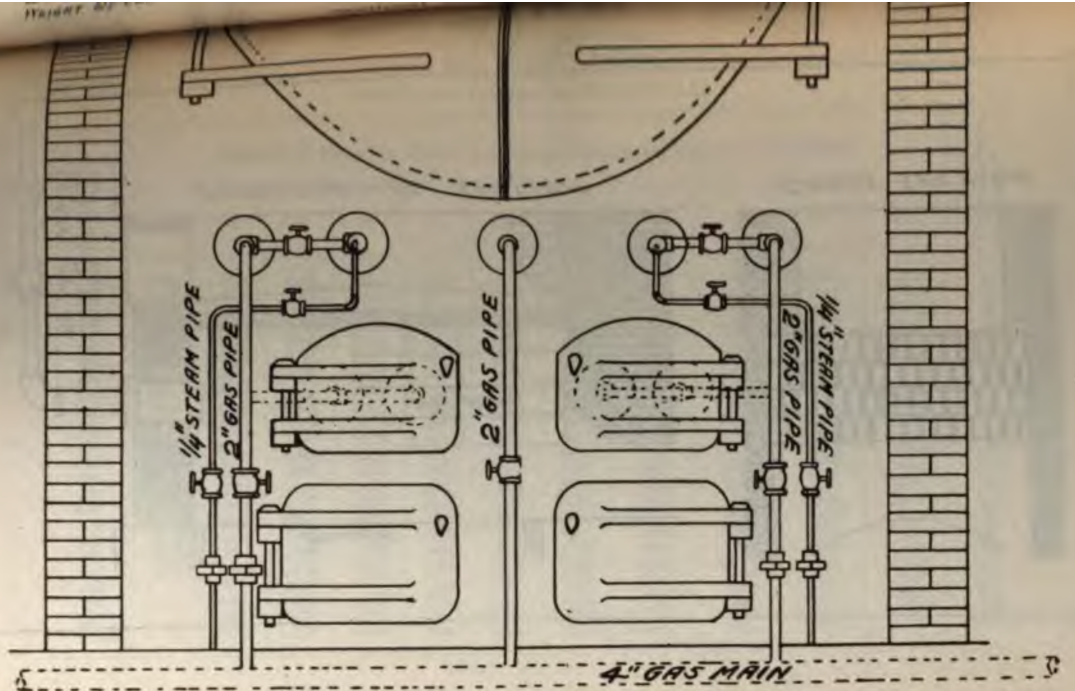


The Branch Crude Oil Burner.
Fig 84-2.

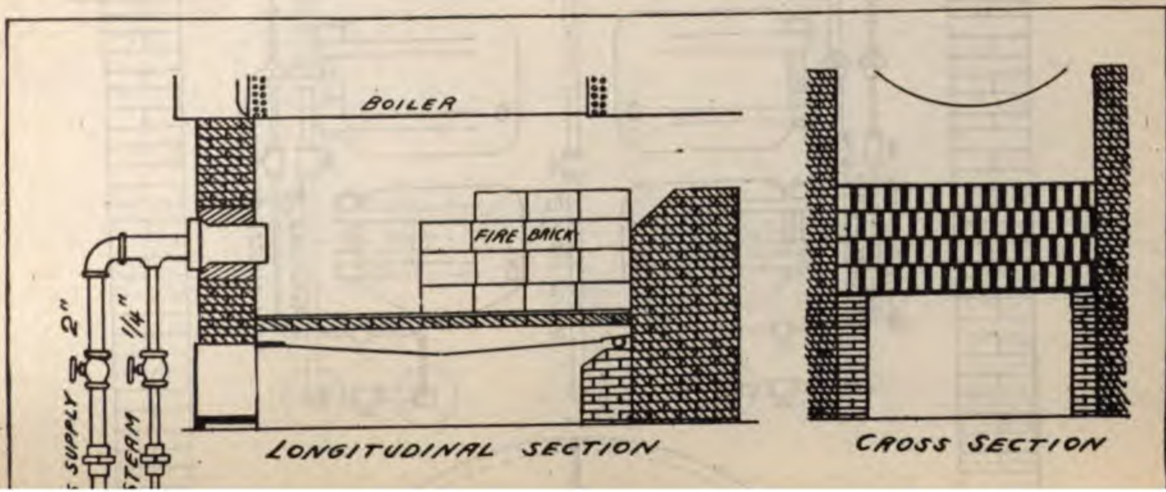


A Complete Oil Burning Installation.
Fig.84-3.


REGULATOR.
AIR REGULATOR
MIXER.
AIR
AIR
STEAM JACKET
STEAM JACKET
LOCKNUT
LOCK NUT
2" GAS PIPE
STEAM OPENINGS
1/4" STEAM PIPE.
DRAWN FULL SIZE
EIGHT 27 LBS.



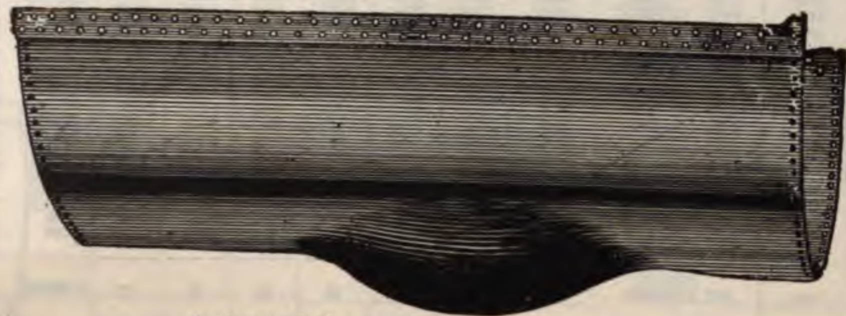
The Proper Location of Gas Burners Under a Boiler.
Fig. 84-5.


BOILER
FIRE BRICK
SUPPLY 2"
STEAM 1/4"
LONGITUDINAL SECTION
CROSS SECTION

Percentage of Saving for Each Degree of Increase in Temperature of Feed-water Heated by Waste Steam.

Initial Temperature of Feed, Degrees	Pressure of Steam in Boiler, Pounds per Square Inch Above Atmosphere											Initial Temperature, Degrees
	0	20	40	60	80	100	120	140	160	180	200	
32	.0872	.0861	.0855	.0851	.0847	.0844	.0841	.0839	.0837	.0835	.0833	32
40	.0878	.0867	.0861	.0856	.0853	.0850	.0847	.0845	.0843	.0841	.0839	40
50	.0886	.0875	.0868	.0864	.0860	.0857	.0854	.0852	.0850	.0848	.0846	50
60	.0894	.0883	.0876	.0872	.0867	.0864	.0862	.0859	.0856	.0855	.0853	60
70	.0902	.0890	.0884	.0879	.0875	.0872	.0869	.0867	.0864	.0862	.0860	70
80	.0910	.0898	.0891	.0887	.0883	.0879	.0877	.0874	.0872	.0870	.0868	80
90	.0919	.0907	.0900	.0895	.0888	.0887	.0884	.0883	.0879	.0877	.0875	90
100	.0927	.0915	.0908	.0903	.0899	.0895	.0892	.0890	.0887	.0885	.0883	109
110	.0936	.0923	.0916	.0911	.0907	.0903	.0900	.0898	.0895	.0893	.0891	110
120	.0945	.0932	.0925	.0919	.0915	.0911	.0908	.0906	.0903	.0901	.0899	120
130	.0954	.0941	.0934	.0928	.0924	.0920	.0917	.0914	.0912	.0909	.0907	130
140	.0963	.0950	.0943	.0937	.0932	.0929	.0925	.0923	.0920	.0918	.0916	140
150	.0973	.0959	.0951	.0946	.0941	.0937	.0934	.0931	.0929	.0926	.0924	150
160	.0982	.0968	.0961	.0955	.0950	.0946	.0943	.0940	.0937	.0935	.0933	160
170	.0992	.0978	.0970	.0964	.0959	.0955	.0952	.0949	.0946	.0944	.0941	170
180	.1002	.0988	.0981	.0973	.0969	.0965	.0961	.0958	.0955	.0953	.0951	180
190	.1012	.0998	.0989	.0983	.0978	.0974	.0971	.0968	.0964	.0962	.0960	190
200	.1022	.1008	.0999	.0993	.0988	.0984	.0980	.0977	.0974	.0972	.0969	200
210	.1033	.1018	.1009	.1003	.0998	.0994	.0990	.0987	.0984	.0981	.0979	210
220	. . .	.1029	.1019	.1013	.1008	.1004	.1000	.0997	.0994	.0991	.0989	220
230	. . .	.1039	.1031	.1024	.1018	.1012	.1010	.1007	.1003	.1001	.0999	230
240	. . .	.1050	.1041	.1034	.1029	.1024	.1020	.1017	.1014	.1011	.1009	240
250	. . .	.1062	.1052	.1045	.1040	.1035	.1031	.1027	.1025	.1022	.1019	250

Table No. 9.



A Bag or Bulge in Boiler Plate.
Fig. 85.

Vertical Lift. Feet.	Feedwater at 60 .		Feedwater at 75 .		Feedwater at 100 .	
	Starting Pressure.	Stopping Pressure.	Starting Pressure.	Stopping Pressure.	Starting Pressure.	Stopping Pressure.
2	15	155	15	145	20	120
4	18	150	18	140		
6	20	142				
8	25	135	25	125		
10	30	125	30	115	35	90
12	35	118				
14	40	110				
15			50	85	45	70
16	45	102				
18	50	90				
20	55	85	55	75		
22	55	75				

Range of Injectors.
Table No. 10.

Total Stored Energy of Steam Boilers.

TYPE.	Area of		Pressure Lbs. Per Sq. Inch.	Rated Power, H. P.	Available Stored Energy in			Max. Hgt. of Projection.	
	Grate Surface	Heat Surface.			Water.	Steam.	Total.	Boiler.	Total.
	Sq.ft.	Sq.ft.			Ft. Lbs.	Ft. Lbs.	Ft. Lbs.	Ft.	Ft.
...Cylinder	15	120	100	10	46 605,200	676,698	47,281,898	16913	5514
[illegible]	36	730	30	60	57 572.750	709,310	58,260 060	3431	1314
...Cylinder	23.	400	15.	35	80 570 050	2,377,357	82,949,407	12243	6076
... Tubular	30	852	75	60	50,008,790	1,022,731	51,031,521	5372	2871
...motive	20	1200	125	600	64,452,270	1 766 447	66,218,717	3319	2348
... Marine	32	768	75	300	71,272,35.	1,462 430	72,734,800	2889	1873
...& Ret. Tub.	72.5	2324	30	200	90 531,490	1,570,517	92,101,987	1684	931
...Tube	100	3000	100	250	108,346,670	1,311,377	109,624,283	2030	1626

Table No. 11.

CHAPTER VI.

QUESTIONS AND ANSWERS ON PRECI CHAPTERS.

Q. What is the principal boiler attachment?
A. The furnace.

Q. Into what classes are furnaces divided?
A. Into straight-draft and down-draft furna cording to the direction taken by the draft.

Q. What is a steam pressure gauge?
A. It is a gauge attached to the boiler to the amount of pressure in the boiler.

Q. How is this pressure designated?
A. In the number of pounds per square inc the pressure of the atmosphere.

Q. Is this the **absolute** pressure within the
A. No; it is the gauge pressure, the absolu sure being 14.7 pounds in excess of the pressure sl the gauge.

Q. What is meant by **atmospheric** pressure?
A. It is the pressure that exists on all object surface of the earth. It is not felt by us as it is ec i. e., the pressure is exerted equally in all direct

Q. Is this pressure the greater at the sea upon a mountain?
A. It is greater at the sea level, becoming the altitude becomes greater.

Q. For what purpose is a **whistle** attacl steam boiler?
A. For signaling purposes.

Q. What is a feed water heater?
A. It is an apparatus for heating the feed a boiler.

Q. What is the object of heating the feed water?

A. To save fuel, and also the boiler, by decreasing expansion and contraction.

Q. How are feed water heaters classed?

A. Into two classes, designated as closed heaters d open heaters.

Q. What is a closed heater?

A. In this form of heater the feed water is subted to the temperature of the steam by bringing the tal tubes through which the feed water is pumped, in tact with the steam. The steam itself does not come contact with the feed water.

Q. What is an open heater?

A. In this form of heater the steam comes in direct tact with the feed water, which absorbs the heat of steam.

Q. What is a coil heater?

A. This is a form of an open heater in which the ust steam does not come in direct contact with the d water, but passes through coils of pipe submerged in suitable vessel, or heater, containing the water.

Q. What are the chief advantages of a closed ter?

A. It permits the water to be handled by the pump n cold, and by not bringing it in contact with the ext steam it does not mingle with the oil or grease card over from the engine.

Q. What form of heater is most commonly used?

A. The open heater, owing to its simplicity.

Q. What is a feed water purifier?

A. It is a form of a feed water heater in which the water is heated by live steam to a sufficiently high erature to precipitate most of the scale forming subs in the water.

Q. What is an **economizer?**

A. It is a form of a feed water heater in wh
hot gases are utilized before escaping into the c
for heating purposes, instead of the **exhaust** or **liv**
as in other forms of feed water heaters.

Q. What is a steam separator?

A. It is an apparatus designed to **remove** th
oil, dirt and other impurities from a current of s

Q. Into what two classes are separators div

A. Into **baffle** plate separators, and **centrifu**
arators.

Q. Upon what principle do **all** separators de

A. Upon **inertia,** the water or oil being muc
ier than steam.

Q. What is a steam trap?

A. It is an appliance for removing the water
densation from steam pipes, separators, and sim
paratus, without the **waste** of **steam?**

Q. Into what two classes are steam traps c

A. Into **open** traps, and **closed** traps.

Q. What is an **injector** or **inspirator?**

A. It is an apparatus for forcing the feed wa
a steam boiler.

Q. What is a **water column?**

A. It is a tube with its ends connected to th
and water spaces of the boiler, and on which t
gauge cocks and water glass are connected.

Q. What is the object of a **safety** water col

A. To give warning to those in charge of th
in case the water varies above or below the **prop**

Q. How is **grate area** usually designated?

A. In square feet.

Q. What is the object of the **bridge wall?**

A. To bring the flame and heated gases in close contact with the heating surface of the boiler.

Q. Is it necessary to always use a bridge wall?

A. No, especially when oil is burned.

Q. What space should there be between top of bridge wall and shell of boiler?

A. From 6 to 10 inches, depending on size of the furnace.

Q. How thick should the bridge wall be made?

A. 28 inches.

Q. Should each boiler in battery have a separate safety valve?

A. Yes, always, and no valve should ever be inserted between it and the boiler.

Q. Why is a plug cock the best valve to use upon the blow off?

A. Because it has an opening equal to the full diameter of the pipe, and scale or dirt is therefore less likely to prevent it closing tight than when a globe or gate valve is used.

Q. What advantage does the tube or flue add to the boiler?

A. It adds strength, heating surface and a reduced volume of water.

Q. What is the object of the damper?

A. To keep the steam pressure constant by regulating the draft.

Q. Into what two general classes are mechanical stokers divided?

A. Into overfeed and underfeed stokers.

Q. What is the chief advantage in the use of a mechanical stoker?

A. It avoids the constant opening of the fire doors.

CHAPTER VII.

BOILER MANAGEMENT.

Care of Boilers.—Both the safety and the economi
operation of boilers require that every care should
taken of them, and that every precaution be obser
in their operation. While a boiler is not handsome
appearance and its operation not clean work, there is
piece of machinery that is as **sensitive** to abuse as
ordinary steam boiler. The principal care of a bo
is the **proper firing** of same, and next in importance
keeping it **clean.** The firing of a boiler is generally
garded as a most simple matter requiring but little sk
and only manual labor. This is a great mistake, for
proper firing of a boiler consists of much more th
merely shoveling the coal into the boiler furnace. Th
are certain requirements which must be observed m
or less applicable to all steam boilers, and which requi
ments can only be learned by study and hard work. T
first requirement is the starting of the fire under the c
boiler, and to do this there is both a right and a wro
way. The right way is to start the fire so as to b
slowly at first, so that all parts of the boiler and setti
may become heated gradually and evenly, permitting
boiler to expand uniformly throughout, thus avoid
all strains and injury to the metal. If on the contra
a hot fire be made at the start, the upper part of
boiler will be heated to a high temperature before
lower part has been scarcely warmed. This is due
the cold water remaining in contact with the lower pl
thus keeping them cool while the upper part of
boiler, not having the water on one side of the sh
rapidly becomes heated.

The necessity of keeping water in contact with **one side** of all metal of a boiler which is exposed to the direct heat of the furnace or the heated gases, has already been stated. This is required since iron or steel when heated **above 600** degrees Fahrenheit becomes weaker, and it is therefore necessary to prevent a dangerous increase of the temperature of the metal above that temperature, and this can only be done by keeping the water in contact with the metal.

Cleaning Boilers.—The work of cleaning a boiler consists of first removing the handhole and manhole plates after the boiler has been emptied. The mud and loose scale is then scraped out, and the whole interior of the boiler thoroughly rinsed with a hose. If scale has accumulated on the tubes and other heating surfaces, it must be scraped off before it becomes so thick as to cause the overheating of the metal.

The scale on the plates over the fire and around the braces and stays can usually be removed with a hammer and chisel, but **great care** should be taken not to cut into the metal. The scale on the tubes in horizontal boilers can usually be removed by a chain. To use a chain it is only necessary to wrap it around the tube and pull it back and forth. If the boiler is very badly scaled it will require two men to do this work successfully.

The removal of scale by **mechanical** means should only be done when it is absolutely necessary. Proper precautions should be taken to prevent the formation of scale by the use of proper boiler compounds or water purifiers, such a method not only being more economical, but safer in every way than any mechanical method. In using a boiler compound, first have the feed water analyzed by a reliable chemist and then select a compound especially for that particular quality of feed water;

or what is better, have a compound made up especially for the feed water from the analysis.

When Cleaned.—How often a boiler should be cleaned will depend chiefly on the **amount** of water the boiler is evaporating, and upon the **quality** or **purity** of the water.

In some cases a boiler will require cleaning every week, while other boilers must be cleaned once every two weeks, or in many instances only once a month. The **average** time a boiler can be economically operated without being cleaned is about three weeks, and should the boiler be equipped with mechanical cleaners, the time can then be extended to about once every four weeks.

Deterioration.—All boilers are subject to rapid deterioration from the time they are first constructed to their condemnation as unsafe for further use. To avoid such deterioration as much as possible, the exterior of all boilers should be carefully covered so as to protect them from the weather or from any water dripping upon them. When boilers are not in service this deterioration continues, though every precaution is taken against it.

To avoid this as much as possible the boiler should be carefully cleaned, including the furnace, ash pit and combustion chamber, immediately upon being cut out of service. All valves and joints should be made **tight**, and the boiler setting put in good condition. After this is done, to further prepare the boiler for a period of idleness, 40 or 50 pounds of soda should be placed along the bottom of the boiler, and the boiler then **filled** up to the highest water level. All valves and the damper should be closed tight.

Boilers Newly Set.—The greatest care should be taken in heating up newly set boilers. The fire should not be lighted under the boilers for at least **ten days**

after the setting of same, as at least this length of time is required to enable all parts of the mason work to set and harden properly. When the fire is started under a newly set boiler for the first time, it should be a very small one, only sufficient to moderately warm all parts of the brick work. This slow fire should be kept up for at least twenty-four hours and not increased but slightly before the second or third day. **Three full days** should elapse before any steam is raised on the boiler.

When steam is raised for the first time, it should not be allowed to go above 4 or 5 pounds pressure, and the steam should then be sent through all the pipes and through the engine before any attempt is made to put them under pressure.

The **object** of these precautions is to prevent injury from any sudden expansion, the masonry not having hardened and the mortar still being green.

Care of Water Tube Boilers.—The soot and ashes collect on the **exterior** of the tubes in this form of boilers, instead of on the interior of the tubes as in fire tube or shell boilers, and such soot and ashes must be as carefully removed in one case as in the other. In this form of a boiler a blow pipe and hose is used through openings left in the brick work. The scale which collects on the **inside** of the tubes of these boilers, is much more difficult to remove than in fire tube boilers, since such scale cannot be reached by an ordinary scraper, but must be bored or **drilled** out. There are a number of contrivances which successfully accomplish this object on the market, but they are all more or less open to the same objection which applies to all mechanical devices for cleaning boilers.

Operation of Boilers.—Before filling the boiler with water a careful examination should be made to see that

nothing has been left inside of it, as it often happ a tool or piece of oily waste, etc., is overlook which may cause a burnt sheet or other damag boiler. The manhole and handhole plates shou be replaced, care being taken to see that the gasl in good condition. It is usual to place a mix cylinder oil and graphite on the outer surface of ket, so that it may be removed without tearin permitting the gasket to be again used. Thes hole and manhole plates must be properly repla secured in order to prevent leakage. Should su age occur, it is rarely that it can be stopped by ing, and it will therefore necessitate blowing th down before a proper joint can be made.

Water Required.—The boiler should then b until the water shows at least half way up in th glass, thus insuring that the water covers all p the boiler that are exposed to the action of the hot gases.

Filling the Boiler.—The boiler can be fill the city mains, provided the pressure is sufficien it to the required height. Should there not be s pressure to do so, it will then be necessary to use or to fill with a steam or hand pump. While th is filling, means should be provided for the es the **air** contained therein, otherwise the pressure from the air on the inside of the boiler will prev boiler from filling fast, or may prevent it from filled to the proper height. It is usual therefore the top gauge cock open, or a manhole plate ca off while filling, but care should be taken to see manhole is properly secured before attempting steam. As **air** is a poor conductor of heat, the c left for its escape should not be closed until stea

rom them, then they should be at once closed e steam pressure can be raised as soon as pos- hout forcing the fires. As soon as sufficient has been raised, the feed pump or injector started to see that they are in proper working l then the water glass, gauge cocks and all ould be tested by opening and closing them. st never be **assumed** that they are in good con- t they must be **known** to be so from actual

ng **the Boiler into Service.**—This is done by ening the stop valve with which each boiler supplied, thus permitting the steam to flow he engine and the other mechanism in the

d this valve be opened too quickly, it will dden change in the temperature and excessive of the piping, thereby causing a **water ham-** e piping, and **priming** in the boiler. Where ore boilers, usually designated as a battery of re all connected to the same header or steam pressure must first be **equalized** between the boilers before connecting same, in order to pre- dden rush of steam from one boiler to another. ssure on all the boilers should not vary over s before it is safe to connect, or cut in, the dif- ilers. At all times when the boiler is in use, should be maintained at a **constant level**, as variation in same, means a variation in the ssure which would at once effect the opera- e entire plant. In order to maintain a constant d water must be regularly supplied. Should any time go out of sight, and the true level opening the lower gauge cock and gauge

glass connections, the fires must be at once **deadened** by throwing fresh coal on the same, or covering with ashes, so that the pressure will fall as low as possible without the introduction of feed water or the stopping of the engine. **Do not touch the safety valve,** nor open any of the valves which may cause a sudden **fluctuation** of the water level in the boiler, as this will bring the water in contact with the highly heated metal, causing a sudden increase of pressure by the rapid evaporation of same. By keeping the engine running the steam can be worked off, thus lowering the pressure. The pump and injector should not be started, as this would force the cold water into the boiler, and against the overheated plates.

When a steam pipe bursts the water level is quickly lowered by the rapid discharge of the steam, therefore the fires must be at once deadened to save the top row of tubes, which will soon become left without water around them and exposed to the heated gases.

The fires must **always** be deadened as quickly as possible in case of any accident causing a sudden release of the steam, such as the melting of a fusible plug, the plug from a stop or blow-off cock blowing out, etc.

In case of all such accidents, the first thing which demands the attention of the engineer or fireman in charge, is the **amount** of water in the boiler and the pressure of the steam.

Regulation of Feed Water.—When the boilers of a battery have been cut into service, the **feed water** for same must next be carefully regulated. Each boiler has its own check valve and feed stop valve, all the boilers being usually supplied from one pump. The quantity of feed water admitted to each boiler is regulated by its own feed stop valve.

When the water gets low in any boiler, its feed stop valve must be opened wider, and at the same time the feed stop valves on one or more of the other boilers in operation must be partially closed, thus forcing the feed water into the boiler or boilers requiring it.

Shutting Down.—Shortly before the time for shutting down for the night, the boiler should be filled to the top of the water glass, so as to allow for evaporation, or any leakage during the night. This also insures sufficient water in the morning to permit the blowing out of a portion before raising steam, as should always be done.

The fires should next be banked, and all the steam valves closed tight, including the valves at the top and bottom of the gauge glass. The damper should be also closed, but not tight as an opening should be left to permit the escape of the gases from the banked fire during the night, up the chimney.

Starting Up.—On entering the boiler room the first thing the engineer and fireman should observe, is the quantity of water in the boiler. To ascertain this, both the water glass and the gauge cocks should be tried. Should the water level not be too low, the banked fires should then be spread over the grates, and the damper regulator opened.

Before the pressure begins to rise, the blow-off cocks should be opened, and the boiler blown down about 3 or 4 inches as shown in the gauge glass. This should be done every morning, in order that the boiler may be freed as much as possible of all the impurities in the water that have settled during the night. Only such impurities in the water as are held in mechanical suspension can be removed in this way. All the other impuri-

ties being held in **solution,** can only be removed by chemical or other means.

While blowing down a boiler, the blow-off must **never** be left while it is open by the engineer or fireman who is in charge.

The water level in a boiler should never be allowed to fall below the first gauge cock, it being the lowest gauge cock; for when the water gets **below** this point all the top row of tubes are left **uncovered** with water.

Priming.—This is simply the water in the boiler boiling over, and being carried into the steam pipes and thence to the engine, where it may cause considerable damage.

The most common causes of priming are:

(1) Insufficient boiler power.
(2) Defective design of boiler.
(3) Water carried too high.
(4) Irregular firing.
(5) Sudden opening of stop valve.

The first, or insufficient boiler power, is the most common cause of priming. The **only** remedy is to **increase** the boiler capacity of the plant, or **decrease** the amount of work required of the boiler.

When the water surface of the boiler is too small, the steam escapes from the water with difficulty, and, on account of its velocity, carries with it small particles of water which combine with the condensed steam in the pipes and are carried over into the cylinder of the engine.

Water being practically **incompressible,** when it more than fills the clearance space between the piston and the cylinder head, a broken head, or other damage to the engine, is the result.

By the use of a **separator**, the entrained water which is carried over from the boiler can be prevented to a large extent from reaching the engine, but there is always danger of "flooding," or the separator not being properly drained.

It is evident that the use of a separator cannot stop the cause of priming, but only can prevent it to a considerable extent.

Priming can be partially remedied by carrying the water low in the boiler, but this not only decreases the efficiency of the boiler, but may also cause a burnt tube or plate.

Foaming.—Unlike priming, foaming is due entirely to the condition of the water. The water in a boiler does not lift in foaming, as it does in priming, but simply foams over, due to the dirt or grease contained in it.

While foaming and priming come from entirely different causes, the resulting damages are usually the same.

Foaming can best be remedied by using the surface blow-off. If there is no surface blow-off, the bottom blow-off should then be used.

The only effective remedy is the use of pure water.

In Table No. 17 is given the analysis of the water used in different cities, showing their scale-forming ingredients.

WATER, ITS IMPURITIES AND TREATMENT.

Properties.—Water is composed, by volume, of oxygen 1 part, hydrogen 2 parts; or, by weight, 88.9 parts oxygen, 11.1 parts hydrogen. It is slightly compressible at the rate of 1/100 of an inch in 18.10 feet by each 15 pounds per square inch pressure. It has a greater solvent power than any other known liquid, and it is due to it

absorbent power that it is rarely found pure or free from foreign substances in solution. Like other liquids, it transmits pressure equally in **all directions**, unchanged and without loss of power. A standard United States gallon of fresh water weighs 8 1/3 pounds and contains 231 cubic inches. A cubic foot weighs 62½ pounds at its greatest density (39.2 degrees Fahrenheit), and contains 1,728 cubic inches, or about 7½ gallons. Under atmospheric pressure it boils at 212 degrees Fahrenheit and freezes at 32 degrees Fahrenheit. When evaporated into steam or frozen into ice, water gives up nearly all it contains in solution, so that steam and ice are practically pure. One cubic foot of water expanded into steam, becomes **1,646** cubic feet at atmospheric pressure.

Impurities.—Water can be freed from substances held in mechanical suspension by **filtration,** but the filter does not remove those chemically combined with it. It is therefore apparent that water may be clear and palatable to the taste, as most spring waters are, and at the same time contain mineral impurities very detrimental for steam purposes. To find the pressure in pounds per square inch of a column of water, multiply the height in feet by .434. Approximately every foot of elevation is equal to one-half pound pressure per square inch. This allows for ordinary friction. The mean pressure of the atmosphere is usually estimated at 14.7 pounds per square inch, so that with a perfect vacuum it will sustain a column of mercury 29.9 inches, or a column of water 33.9 feet high.

All water used for boiler purposes, unless it is rain water collected from roofs, or distilled water, contains more or less **scale-forming** material in solution.

ANALYSIS OF ST. LOUIS WATER.

Made January, 1906.

and Volatile......	2.572 Grs. Per. U. S. Gallon.
Chloride	.810 Grs. Per. U. S. Gallon.
Sulphate	.466 Grs. Per. U. S. Gallon.
Sulphate	4.139 Grs. Per. U. S. Gallon.
um Carbonate	1.924 Grs. Per. U. S. Gallon.
um Sulphate.......	a trace.
lids	9.911 Grs. Per. U. S. Gallon.
bonic Acid........	1.749 Grs. Per. U. S. Gallon.

water will give a very hard scale of Calcium and Magnesia. It will become corrosive on ation.

SIS OF SCALE FROM ST. LOUIS WATER.

Made January, 1906.

and Volatile....................	5.0 per cent.
Carbonate	32.7 per cent.
Sulphate	46.5 per cent.
....	14.3 per cent.
de and Alumina................	1.5 per cent.
....	a trace.

ical Characteristics.—
kness, ¼-inch, 6.4 m.m.
lness, very hard.
cture, crystalline and amorphous.

ctions for the Use of the Standard National Boiler d.—As a first application use 20 pounds of d to each 100 H. P. boiler. This quantity must pplied whenever and immediately after a boiler washed out and filled up with **fresh water.**

An additional ¾ pounds per 100 H. P. must be solved every day and pumped into the boiler.

Dissolve the compound in about ten times the qu tity of **hot water.**

Open the blow-off every 10 hours for an instant o

Clean and thoroughly wash out each boiler every days, unless water is very bad, then every two we until nearly all old scale has been removed, then cl boilers every 30 days.

Inspection and Laws Governing Same.—The sponsibility for the proper inspection of all boilers attachments rests upon the engineer in charge, it be one of his most **important duties.**

He should know best the condition of all appara in the plant of which he is the engineer, and especi of the boiler as it is under his **constant observation.**

It is the duty of the engineer or fireman to at o remedy any defect which may appear in a boiler or attachments, and if this cannot be done to report it his employer, and if it is deemed necessary by him safety, to **shut down** the plant.

The public safety can alone be secured by all b ers and their attachments being placed in charge of co petent engineers and firemen, whose competency ha been ascertained and properly certified by proper o cials. This is especially true since the introduction compound engines, with the high boiler pressure nec sary for their operation, together with the many ot requirements of the modern steam plant.

Every part of a boiler, both external and intern should be carefully examined and tested at least or **every year** by conscientious and competent officials.

Tests.—There are two principal ways of inspect a boiler, viz.: by the **hammer test,** and by the **hyd static test.**

Hammer Test.—In this inspection of a boiler, a hammer is used with which all the plates, stays and tubes are struck, and their soundness thereby determined. All sound plates and tubes when struck give forth a clear bell-like ring, while those defective give forth a dull, hoarse sound.

The sound from a loose or broken stay is quite different from that of a taut one in good condition, and the difference can soon be distinguished.

Hydrostatic Test.—To inspect a boiler by this test, it is necessary to fill the boiler full of water, and apply a pressure by means of a pump, which pressure should be considerably more than the working pressure desired to be carried on the boiler.

While such a test will not reveal **weak places** in the boiler, it will show all **leaks** in the boiler and fittings, and will insure the boiler to safely carry the pressure placed on it when properly operated.

Objections and Precautions.—In using the hydrostatic test, there is danger of **straining** the plates beyond their elasticity should an excess of pressure be placed on the boiler, and thereby permanently injuring same. Therefore, it is necessary that only the pressure **required** for safety, be placed upon the boiler.

Again, all **air** must be allowed to escape from the boiler while it is being filled, as should the boiler **burst** while containing air, it would cause the pieces to be thrown with great force.

The **hammer** test is generally preferred for **old** boilers, and the **hydrostatic** test for **new** boilers. To insure safety, **both** tests should be applied whenever it is deemed advisable by the engineer or inspector.

All the cities and many of the states now have **laws** requiring the thorough inspection of all boilers and their attachments.

St. Louis Ordinance.—The ordinances enacte the City of St. Louis prescribing the manner of in tion of all boilers in that city and the enforceme same, has long been taken as a model by different and cities throughout the country, though many provisions now need revision in order to make ther plicable to the requirements for safety of modern p plants. These statutes and ordinances are in the similar to the following section taken from the St. ordinance prescribing the manner of inspection:

Manner of Inspection.—The manner of inspe shall be substantially as follows: The owners of boilers and users shall have the option of takin hammer test or the hydrostatic test; also of ele whether the Inspector of Boilers and Elevators o of the assistant inspectors, mentioned in this ch and employed and paid by the insurance companies, make such test. If the hammer test be asked fo examination shall be thorough and searching upon part of the boiler, both internally and externally, in ing all fittings and attachments. If the hydrostati be asked for, each boiler shall be tested by the hyd pressure one-fourth greater than the ordinary wo steam pressure used, and the certificate of inspe herein provided shall state the maximum pressu which any boiler may be worked. In case a defect be discovered in any boiler or attachment thereto Inspector of Boilers and Elevators shall report the to the owner or user of said boiler or boilers, and the facts of the case in writing, giving a descripti the particular locality in which each defect ma found, and whether of a dangerous character and n sitating immediate repair. If the Inspector of Bo and Elevators shall at any time find a boiler whic

dgment, is unsafe, after inspecting same, he shall nn its further use. All boilers to be tested by the tatic pressure shall be filled with water by the s or users, and they shall furnish the necessary equired to work and handle the pumps in apply- e test. When leaks occur which prevent a suc- test, the Inspector of Boilers and Elevators shall a second test, upon receiving notice that all leaks een repaired. If, upon making a second test, the or boilers are still defective, he shall for each sub- t test, collect an additional inspection fee, but in shall he give a certificate until fully satisfied of ety of the boiler or boilers. All certificates of in- n shall be for one year and no longer. Any or user of any boiler or boilers insured by any boiler inspection and insurance company duly au- d to transact business in the State of Missouri, pon his request, have the hydrostatic test applied nnually, without extra charge, by the assistant inspector of such company, as provided in this .

eparing Boilers for Inspection.—When an internal ion of a boiler is to be made by an inspector, the er should be notified several days in advance, so may have ample time in which to prepare both iler and himself for the work to be done. The s usually designated by law, and should not be an 10 days in advance of inspection.

ne fires should be drawn and the boiler permitted l down at least 24 hours before the time set for rival of the inspector. Just before the inspector the boiler, it should be thoroughly rinsed out with cold water. The ash and soot should be thor- y cleaned away from the grates, ash pit and com-

bustion chamber, so that the inspector will have easy access to all parts of the interior of the boiler and settings.

The engineer should render every assistance in his power to the inspector, and, as a rule, be guided by his advise. The instructions of the inspector should be faithfully carried out in every detail for it is an exception to find an incompetent or unworthy inspector.

As the public safety depends to a large extent upon a careful and thorough inspection of a boiler and all its attachments, only competent and conscientious men should be employed for this purpose; and it is to the credit of municipalities and insurance companies that they have always maintained the highest standard required for this work, and have rarely, if ever, allowed mercenary motives to endanger the safety of the public.

Explosions.—While there have been many **theories** as to the cause of steam boiler explosions, there is but one thing certain, and that is that an **over pressure** of steam is the direct cause of all boiler explosions. This over pressure may be due to any one of many causes, but it is safe to say that so long as the pressure does not exceed the strength of the boiler, that there will be no explosion.

Causes.—Among the reasons why a boiler is unable to bear the working pressure may be named: (1) Defective design as to the amount of pressure the boiler is required to stand. (2) Deterioration, that is, reduction of the strength of the boiler from corrosion, incrustation and wear. (3) Defective workmanship or material. (4) Incompetent attendant.

Defective Design.—The boiler may be insufficient or improperly stayed. The openings for manholes, domes, etc., may not have been properly reinforced, thus

From this it can be seen that an ordinary return tubular boiler under 75 pounds pressure, has stored within it sufficient energy to blow it over **a mile** into the air.

To resist this enormous energy stored in boilers, with the ever increasing demand upon them, and the destruction that must follow the sudden release of same, more perfectly constructed boilers and more competent engineers in charge of same, are necessary.

The **responsibility** for the preservation of the public safety from such explosions, rests upon the boiler maker and the steam engineer, and no class of men feel this responsibility more, or endeavor to more faithfully discharge their duty, than the **steam engineer.**

RULES FOR MANAGEMENT AND CARE OF STEAM BOILERS.

Hartford Steam Boiler Inspection and Insurance Co.

1. **Condition of Water.**—The first duty of an engineer, when he enters his boiler room in the morning, is to ascertain, by blowing out water column or trying gauge cocks, how many gauges of water there are in his boilers. **Never start nor unbank the fires until this is done.** Accidents have occurred, and many boilers have been entirely ruined, from neglect of this precaution.

2. **Low Water.**—In case of low water, immediately cover the fire with ashes, or, if no ashes are at hand, use **fresh coal,** and close ash pit doors, and leave fire doors open. If oil or gas is used as fuel, shut off the supply from burners. Don't turn on the feed under any circumstances, nor tamper with or open the safety valve. Let the steam outlets remain as they are.

3. **In Case of Foaming.**—Close throttle, and keep closed long enough to show true level of water. If that

level is sufficiently high, feeding and blowing will usually suffice to correct the evil. In case of violent foaming, caused by dirty water, or change from salt to fresh, or **vice versa,** in addition to the action above stated, check draft, and cover fires with fresh coal, or shut off the supply from burners where oil or gas is used for fuel.

4. **Leaks.**—When leaks are discovered they should be repaired as soon as possible; if leaking occurs at longitudinal seams, notify the company's inspector at once.

5. **Blowing Off.**—Clean furnace and bridge wall of all coal and ashes. Allow brick work to cool down for two hours at least before opening blow. A pressure exceeding 20 pounds should not be allowed when boilers are blown out, and where practical to run water out without pressure, the boilers should be cooled down thoroughly before emptying, which will render the washing out of scale and deposit easier.

Generally boilers should be blown down two gauges once or twice a day, and entirely emptied once a week, unless the condition of feed water renders more frequent emptying necessary. When surface blow cocks are used, they should be often opened for a few moments at a time.

6. **Filling Up the Boiler.**—After blowing down **allow the boiler to become cool** before filling again. Cold water pumped into hot boilers is very injurious from sudden contraction.

7. **Exterior of Boiler.**—Care should be taken that no water comes in contact with the exterior of the boiler, either from leaky joints or other causes. Particular care should be taken to keep sheets and parts of boilers exposed to the fire, perfectly clean, also all tubes, flues

and connections well swept. This is particularly necessary where wood or soft coal is used for fuel.

8. **Removing Deposit and Sediment.**—To prevent danger from overheating, causing distortion or cracking of sheets, and to aid in the economical production of steam, the internal surfaces should be kept free from scale or deposit, and the boiler should be opened frequently for examination and cleaning. The condition of feed water determines the time that may elapse between cleanings.

9. **Safety Valves.**—Safety valves should be tried daily, as they are liable to become fast in their seats, and useless for the purpose intended.

10. **Safety Valve and Pressure Gauge.**—Should the gauge at any time indicate the limit of pressure allowed by this company, see that the safety valves are blowing off. In case of difference notify the company's inspector.

11. **Gauge Cocks, Glass Gauge.**—Keep gauge cocks clear, and in constant use. Glass gauges should not be relied on altogether.

12. **Blisters.**—When a blister or lamination appears there must be no delay in having it carefully examined, and, if severe, notify the company's inspector.

13. **General Care of Boilers and Connections.**—Under all circumstances keep the gauges, cocks, etc., clean and in good order, and things generally in and about the engine and boiler room in a neat condition.

14. **Getting up Steam.**—In preparing to get up steam after boilers have been open or out of service, great care should be exercised in making the man and hand-hole joints. The boilers should be vented through the safety valve or gauge cocks, and water run in until it shows at second gauge. After this is done, fuel may

be placed upon the grate, dampers opened, and fi started. If chimney or stack is cold and does not dr properly, burn some oily waste or light kindlings at t base. Start fires in ample time so it will not be nece sary to urge them unduly. When steam issues fro the vent, close it and note pressure and behavior of stea gauge while raising steam.

If oil or gas is the fuel used, it is very importa that steam be raised slowly; that is, no faster than wou be possible with coal as fuel. If this precaution is n observed, serious damage to the boiler is liable to resu

Where a boiler is to be cut in with others alrea in operation, watch the one recently fired up until pre sure is up to that of the other boilers to which it is be connected; and, when that pressure is attained, op bleeder valves long enough to thoroughly drain all wat from the steam pipes, and then open the stop valves ve slowly and carefully.

15. **Gas or Oil Fuel.**—When gas or oil is used fuel, care should be used in adjusting the burners, that the flame cannot impinge directly on the heati surface; and the checker-work, where used in such fu naces, should be arranged so that it will not concentra the flame upon the boiler surfaces.

Suitable peep-holes should be provided for obser ing the fire surfaces during operation of the boiler.

Before lighting the fire, the greatest caution shou be observed to see that the drafts are open for a su cient length of time to remove the gas that may ha accumulated in the setting. Never turn on the fuel su ply when starting up, or after snapping out of burn without first introducing a lighted torch or burni waste into the furnace. Disregard of these precautio is liable to result in a serious accident.

In Fig. 85 is shown a bag or bulge in a boiler sheet, caused by the plate becoming overheated, from oil or ste preventing the water from coming in contact with the plate or sheet; as oil is a poor conductor of heat.

In Fig. 83 is shown a common type of a crude oil burner, and a natural gas burner, used in boiler furnaces.

In Fig. 84 is shown the proper installation of an oil burner under a horizontal boiler.

The burners here shown are the Branch burners and furnace installation.

In Fig. 84—1 is shown the proper installation of an oil burner under a water tube boiler.

In Fig. 84—2 is shown two views of the Branch crude oil burner.

In Fig. 84—3 is shown a complete oil burning installation.

In Fig. 84—4 is shown a sectional view of a natural gas burner.

In Fig. 84—5 is shown the proper location of gas burners under a boiler.

In Fig. 84—6 is shown a complete gas burning installation.

CHAPTER VIII.

LEADING TYPES OF BOILERS, WITH SPECIF CATIONS.

The Brownell Vertical Boiler.—In Fig 12 is sho one of the best-known types of a submerged tubu boiler. The following fixtures are usually sent with vertical boilers, the seams being as follows:

Boilers over 36 inches in diameter have shell e tended 8 inches to form ash pit, and have flat base pla

Vertical seams double riveted. All boilers have han holes above flue sheet and at bottom of fire box for clea ing out.

Fixtures for the above boilers include base, grat and doors.

Fittings include glass water gauge, gauge cock 5-inch steam gauge and siphon, pop safety valve, chec valve, stop valve and blowoff valve.

The Kewanee Fire-Box Boiler.—In Fig. 86 is show the ordinary locomotive type of a **fire-box** boiler. It advisable to always purchase these boilers with **wat fronts** and **dry bottoms,** as the ordinary cast iron fro will soon burn out, while the corrosion is objectionab in water bottoms. No **cast iron** lugs, flanges or nozzl should be used, but **steel** required throughout.

WICKES VERTICAL WATER TUBE BOILER.

Construction.—This boiler shown in Fig. 87 consis primarily of two cylinders joined together by straig tubes, which are divided by a fire-brick tile passi through their center into two compartments. The wh

The Kewanee Firebox Boiler.
Fig. 86.

is then erected in a vertical position and surrounded brickwork.

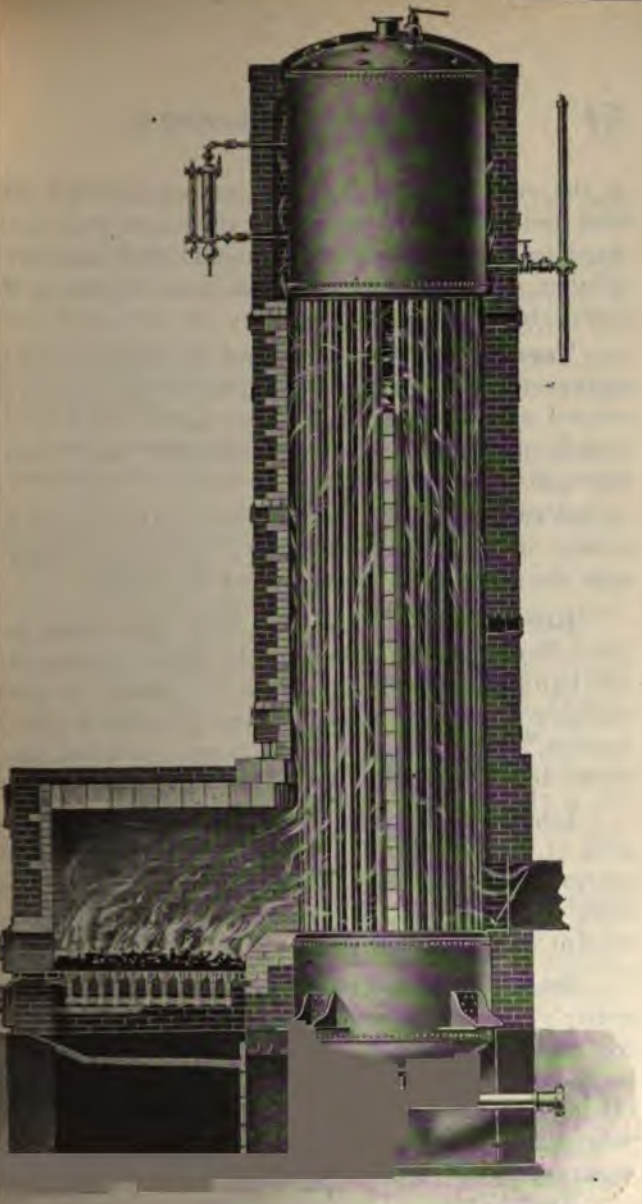
Drum.—The two cylinders are duplicates in th diameter and general construction, but differ in heig and arrangement of convexed heads. The top cylind designated hereafter, from its use, as the steam drum, the longer, the length, diameter and thickness being v ied in accordance with the size of boiler desired and lo requirements.

The bottom cylinder, designated hereafter, from use, as the mud drum, is the shorter, and is varied in dimension as to diameter, length and thickness in acco ance with the power of boiler required and local co tions. Both drums are closed at one end with the t sheet and at the other end with convexed heads.

Tubes.—The mud and steam drums are joined gether by the tubes, which are perfectly straight in th selves, and plumb in position, when expanded into two tube sheets. They are arranged in parallel ro from furnace to stack, with a clear space between r sufficient to permit of introducing a small hoe for purpose of removing any deposit of soot or of sedim which has fallen from the tubes and accumulated on mud drum.

Manholes.—In the convexed head of the steam d one large manhole and a number of handholes are pla and in the shell of the mud drum another manhol placed. This arrangement permits entering the boile the highest and lowest points by simply breaking joints, from which points a perfect examination may made or the tubes thoroughly cleaned.

Tile.—By the introduction of heavy fire brick the tubes are divided into two compartments. The tu in the forward compartment are called the "risers," th



The Wickes Vertical Water Tube Boiler.
Fig. 87.

in the rear compartment the "downcomers," since the heat and the water, mingled with steam, rise in the forward tubes, and both the heat and the water, in solid column, descend among and in those forming the rear compartment.

Travel of Heat.—This gives the heat two complete sweeps through the entire length of the boiler and the second sweep from above downward. The heat in its double passage surrounds completely and closely the tubes in both compartments.

Water Line.—The water line in the boiler is maintained, in the steam drum, at a sufficient height to insure the complete submersion of the tubes.

Baffle Plate.—On a level with the water line, and extending over the tubes in the front compartment, is the baffle plate, which deflects the water of circulation rising, commingled with its steam, directly to the "downcomers," and without splashing and spraying the steam room directly above with globules or masses of water.

Liberating Surface.—Fully two-thirds of the entire area of steam drum is liberating surface, and, as the liberation takes place mainly over the "downcomers," it does so in the quietest manner and in the absence of violent ebulition or turmoil.

Steam Room.—The large steam room is therefore entirely free from water, and the steam outlet is the topmost point,, which is far away from the water line, in large boilers the distance being from 6 to 7 feet. On the other hand, the blow-off is at the very lowest point, and where all impurities are precipitated by gravity and by separation due to the flow of the water of circulation.

Feed Water.—The feed water may be introduced in the steam drum directly into the "downcomers" and far

below the water line, or in the mud drum above the precipitated sediment.

Setting.—The setting of the boiler, which is of brickwork, is arranged so that it is entirely independent of the boiler, and free to expand and contract as its coefficient may dictate, and allow the boiler to expand and contract in accordance with the special laws governing its change of form.

Note how closely confined to the tubes the gases of combustion are after their generation in and leaving the furnace, and how correspondingly absent are the large expansion chambers usually found in boiler settings.

Flow of Heat.—The direct flow of the heat is, by virtue of the draft, over the tile and down by the shortest possible path, or the path of least resistance; while heat of radiation rises naturally and surrounds the steam drum clear to its top, thereby first drying and finally superheating the steam where it leaves the boiler.

Damper.—A single or double wing-damper is placed in the setting at the point of exit of the gases. It is so designed as to allow the quick and easy removal of the wings when cleaning is going on.

Foundation.—The foundation is so designed that by means of a door through the circular brickwork a man can enter underneath the boiler, examine or adjust the blow-off pipe, rivets, and see that the bottom of the mud drum is kept well and heavily painted.

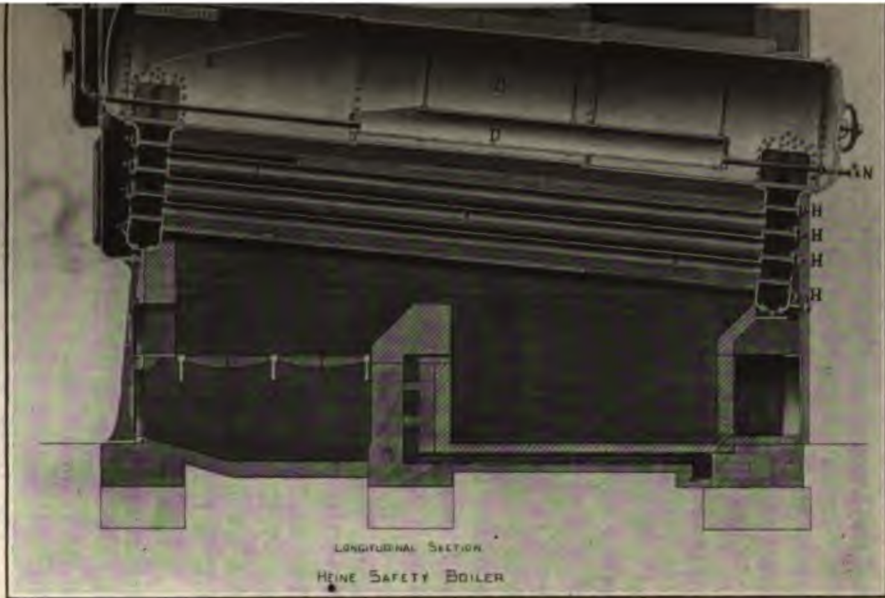
Furnace.—The furnace designed for this boiler is of the "Dutch Oven" type and is built entirely of brickwork. The side walls of this furnace, are made heavy and faced with fire brick, which are laid "headers" around the grate surface. The arch over the furnace is formed of special wedge brick. The weight of the setting is removed from the arch of the furnace by the I

beams shown, and these beams are arranged in box so placed as to permit a constant flow of air bet them, thereby preventing their rise in temperatur consequent expansion.

THE HEINE SAFETY WATER TUBE BOIL

Construction.—This boiler as shown in Fig. composed of lap-welded wrought iron tubes, exte between and connecting the inside faces of two " legs" which form the end connections between tubes and a combined steam and water drum or "s placed above and parallel with them. (Boilers ov horse power have two such shells.) These end bers are of approximately rectangular shape, dra at top to fit the curvature of the shells. Each is posed of a **head plate** and a **tube sheet,** flanged all a and joined at the bottom and sides by a butt str same material, strongly riveted to both. The wate are further stayed by **hollow stay bolts** of hyd tubing, of large diameter, so placed that two stays port each tube and handhole and are subjected to very slight strain. Being made of heavy metal form the strongest parts of the boiler and its n supports. The "water legs" are joined to the sh **flanged and riveted joints** and the drum is cut aw these two points to make connection with inside of leg, the opening thus made being strengthene bridges and special stays, so as to preserve the or strength.

The **shells** are cylinders with **heads dished** to parts of a **true sphere.** The sphere is everywhe strong as the circle seam of the cylinder, which is known to be twice as strong as its side seam. T



The Heine Safety Water Tube Boiler.
Fig. 88.

fore these heads require no stays. Both the cylinder and its spherical heads are therefore **free to follow** their **natural lines of expansion** when put under pressure. To the bottom of the front head a flange is riveted into which the feed pipe is screwed. This pipe is shown in the cut with **angle valve** and **check valve** attached.

On top of shell near the front end is riveted a **steam nozzle** or saddle, to which is bolted a Tee. This Tee carries the **steam valve** on its branch, which is made to look either to front, rear, right or left; on its top the **safety valve** is placed. The saddle has an area equal to that of stop valve and safety valve combined. The rear head carries a **blow-off flange** of about same size as the feed flange, and a **manhead** curved to fit the head, the manhole supported by a strengthening ring outside. On each side of the shell a square bar, the **tile-bar,** rests loosely in flat hooks riveted to the shell. This bar supports the **side tiles** whose other ends rest on the **side walls,** thus closing in the furnace or flue on top. The top of the tile bar is two inches below **low water line.** The bars rise from front to rear at the rate of 1 inch in 12. When the boiler is set, they must be exactly level, the whole boiler being then on an incline, i. e., with a fall of 1 inch in 12 from front to rear.

It will be noted that this makes the height of the **steam space** in front about **two-thirds** the diameter of the shell, while at the rear the **water** occupies **two-thirds** of the shell, the whole contents of the drum being equally divided between steam and water.

The **tubes** extend through the tube sheets into which they are expanded with roller expanders; opposite the end of each and in the head plates is placed a handhole of slightly larger diameter than the tube and through which it can be withdrawn. These handholes

l by small cast iron **handhole plates,** which can ed in a few seconds to inspect or clean a tube. Fig. 88, shows these handhole plates marked ıis cut can be seen the position of these hand- :s, which are held in place by a yoke or crab tside to support the bolt and nut. The plates d with a shoulder in which is placed the gasket, nsuring a tight joint.

e of the shell is located the **mud drum** D, ell below the water line usually paralleled to :hes above the bottom of the shell. It is thus y **immersed** in the hottest water in the boiler. ɔval section slightly smaller than the manhole, strong sheet iron with cast iron heads. It is enclosed except about 18 inches of its upper t the forward end, which is cut away nearly o the water line. Its action will be explained The **feed pipe** F enters it through a loose joint in : **blow-off pipe** N is screwed tightly into its rear l passes by a steam tight joint through the rear he shell. Just under the steam nozzle is placed n or **dry pipe** A. A **deflection plate** L extends front head of the shell, inclined upwards, to tance beyond the mouth or throat of the front ;. It will be noted that the throat of each water rge enough to be the practical equivalent of the e area, and that just where it joins the shell it gradually in width by double the radius of the

ction and Walling In.—In setting the boiler front water leg firmly on a set of strong cast lumns, bolted and braced together by the door dead-plate, etc., and forming the fire front. the fixed end. The rear water leg rests on which are free to move on **cast iron plates** firmly

set in the masonry of the low and solid rear wall. Wherever the brickwork closes in to the boiler broad joints are left which are filled in with tow or waste saturated with fireclay, or other refractory but pliable material. Thus **the boiler and its walls** are each **free** to **move separately** during expansion or contraction, without loosening any joints in the masonry. On the lower, and between the upper tubes, are placed light fire brick tiles. **The lower tier** extends from the front water leg to within a few feet of the rear one, leaving there an upward passage across the rear ends of the tubes for the flame, etc. **The upper tier** closes in to the rear water leg and extends forward to within a few feet of the front one, thus leaving the opening for the gases in front **The side tiles** extend from side walls to tile bars and close up to the front water leg and front wall, and leave open the final uptake for the waste gases over the back part of the shell, which is here covered above water line with a row lock of **fire brick** resting on the tile **bars.** The rear wall of the setting and one parallel to it arched over the shell a few feet forward form the uptakes. On these and the rear portion of the side walls is placed a light sheet-iron hood, from which the breeching leads to the chimney. When an iron stack is used, this hood is stiffened by L and T irons so that it becomes a truss **carrying the weight** of such stack and distributing it to the side walls.

Bridge Wall.—The bridge wall is hollow and has small slotted openings in rear to deliver hot air into the half-consumed gases which roll over the bridge wall into the combustion chamber. It receives its air from channels in the hollow side walls (controlled by small cast iron slides), through a cross flue at the rear end and a number of small flues under the floor of the combustion

as shown in the cut. In the rear wall of the on chamber is an arched opening, closed by a door, which in turn is shielded by a dry fire all easily removable. For special fuels, for revention, etc., there are now to be had various furnaces, automatic stokers, rocking grate bars,

ulation.—The circulation, at first slow, **increases** as soon as steam begins to form. Then the ith which the mingled current of steam and es in the forward water leg will depend on the e in weight of this mixture, and the solid and colder water falling down the rear water leg. imum velocity will be reached when the mix-bout half steam and half water. As the area of at of the water leg is **practically equivalent** to **egate tube area** (offsetting the greater amount friction in the tubes against the reduced area of at), there will be nothing to interfere with the **on of gravity and the full speed will be main-** s long as steam is being made. This circulation well borne in mind. It is forward through the pward through the front water leg, to the rear hell, and down through the rear water leg. At ward throat of the shell the channel slightly en-y reason of two outward flanges of the water leg. flection plate L assists in directing the circula-the water to the rear. Thus the steam bubbles a trend towards the rear, throwing the spray in tion away from the flow of steam. It also has ect of **increasing the liberating surface.** For each of this moving surface of water, as it is deliver-load of steam, sweeps rapidly to the rear, mak-

ing room for the next section, thus constantly presenting a fresh surface for this work.

The shallowness of the water at the front of the shell makes it easier for the steam to pass through; its depth at the rear ensures **a solid body of water** for replenishing the rear water leg and tubes. The height of the steam space in front removes the nozzle far out of reach of any spray; the deflection plate catches and deflects any sudden spurt, while finally the dry pan or dry pipe draws the steam from a large area, from three sides, **thus preventing any local disturbance.**

The action of the **mud drum** is as follows: The feed water enters it through the pipe F about ½-inch above its bottom; even if it has previously passed the best heaters it is colder than the water in the boiler. Hence it drops to the bottom, and, impelled by the pump or injector, passes at a **greatly reduced speed** to the rear of the mud drum. As it is gradually heated to near boiler temperature it rises and flows slowly in reverse direction to the open front of the mud drum; here it passes over in **a thin sheet** and is immediately swept backward into the main body of water by the swift circulation, thus becoming **thoroughly mixed** with it before it reaches the tubes. During this process the mud, lime salts and other precipitates are deposited as a sort of semi-fluid "sludge" near the rear end of the mud drum, whence it is blown off at frequent intervals through the blow-off valve.

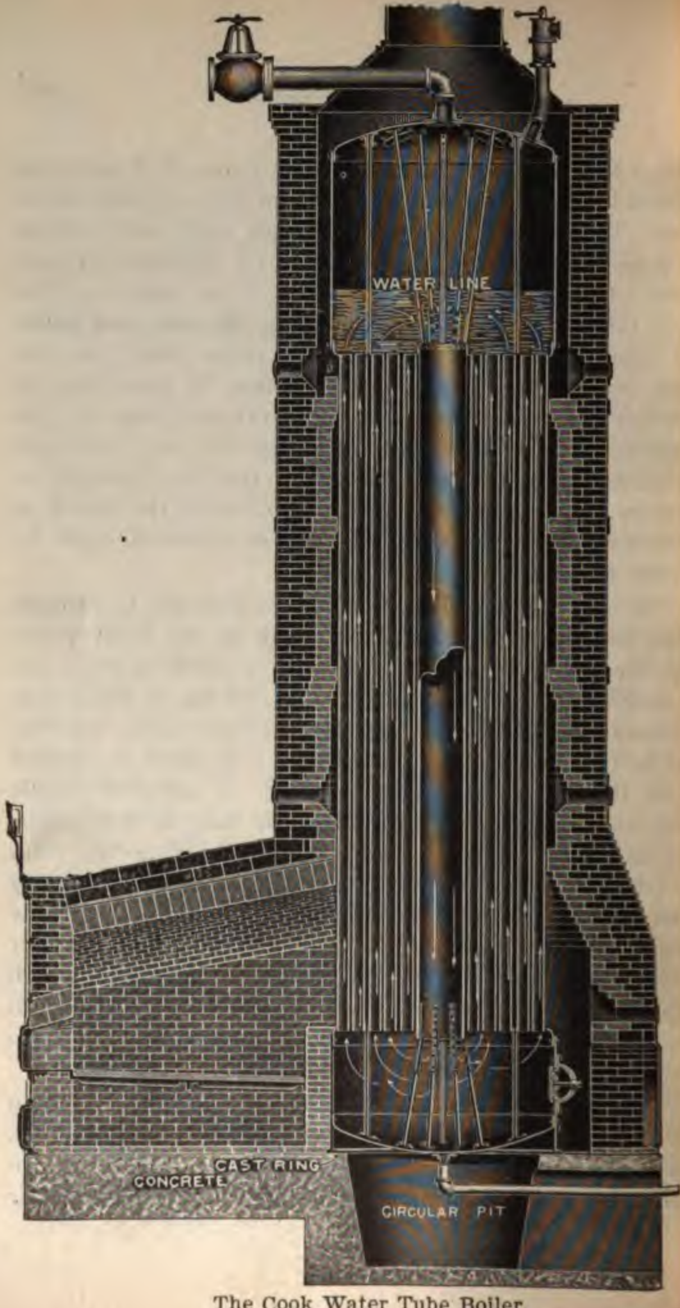
Cleaning.—This explanation of the action of the mud drum shows how **the inside of the tubes may be kept clean.** To keep the **outside clear of soot and ashes** which deposit on, and sometimes even bake fast to the tubes, each boiler is provided with two special nozzles with both side and front outlets, a short one for the

rear, a long one for the front. They are of ⅜-inch gas pipe and each is supplied with steam by a ½-inch steam hose. The nozzle is passed through each stay bolt in turn, and thus delivers its side jets on the three or four tubes adjacent, with the full force of the steam, at the short range of two inches, **knocking the soot and ashes** off completely, while the end jet carries them into the main draft current to lodge at points in breeching or chimney base convenient for their ultimate removal. An inspection of the cuts will show that the stay bolts are so located that the nozzle can in turn be brought to bear on all sides of the tubes. As soon as the nozzle is withdrawn from the stay bolt, this is closed air-tight by a plain wooden plug.

In cleaning a boiler it is only necessary to **remove every fourth or fifth handhole plate in** the front water leg; the water hose, supplied with a short nozzle, can be entered in all the adjacent tubes, owing to the ample dimensions of the water leg. In the rear water leg only one or two handholes in the lower row need be opened to let the water and debris escape. A lamp or candle hung on a wire through the manhead may be held opposite each tube so that it can be perfectly inspected from the front. Once or twice a year, where **the water is very scale bearing**, it may be advisable to take off all the handhole plates of the front water leg and pass a scraper through all the tubes in succession. The ashes which deposit in the combustion chamber are removed through the ash pit door in the rear wall, never allowing it to become more than one-third full.

The Cook Water Tube Boiler.—In Fig. 89 is shown the construction of this boiler, which is extremely simple, consisting essentially of two steel cylinders, connected together by a large number of 4-inch lap welded boiler

10



The Cook Water Tube Boiler.
Fig. 89.

tubes, the ends of which are expanded into the end of the drums.

THE CAHALL VERTICAL WATER TUBE BOILER.

Construction.—This boiler, as shown in Fig. 90, consists of two drums arranged one above the other, made of best mild open hearth flange steel, and connected with 4-inch lap-welded best charcoal iron tubes These tubes are vertical, are perfectly straight throughout their entire length, and are expanded into the drums at each end.

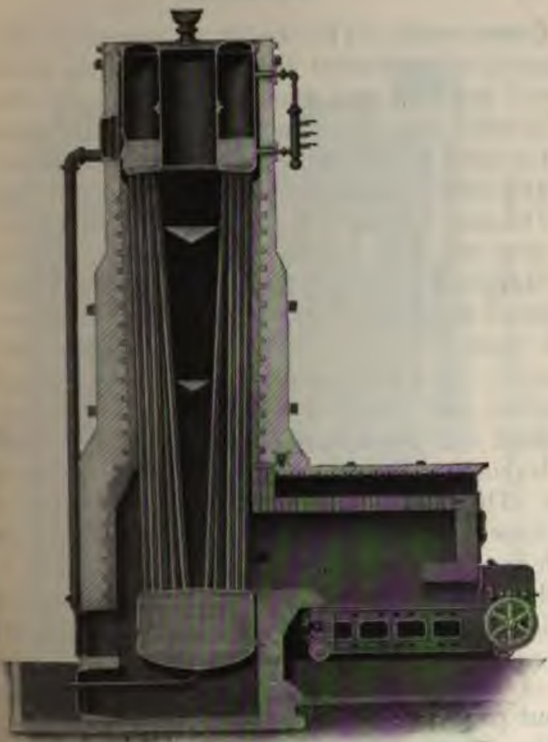
The upper or steam drum has an opening through its center for the exit of waste gases. These gases, although reduced to a very low temperature in passing through the closely grouped tubes of the boiler, will impart most of their retained surplus heat to the metal sides of the passage through this upper drum, thereby tending to slightly superheat the steam in the chamber above. The water line in the upper drum is about 2 feet above the bottom of the drum, the drum itself being about 7 feet high in the clear inside, leaving a space of 3 feet between the surface of the water and the point at which the steam is drawn off from the boilers, which prevents the carrying over of water with the steam, either in the form of supersaturation or mechanical entrainment.

An external circulating pipe comes out from the upper or steam drum, just below the water level, and is
ard, outside the brickwork, to a point
tube sheet of the lower drum, where it
m. There being no steam whatever in
rculating pipe, and no possibility of mak-

ing any, and there being, in the tubes connecting t two drums, steam in greater or less proportions, the sult is (the volume in the external pipe having a co siderably greater specific gravity than the mixture steam and water in the tubes) a very rapid, positive c culation in one direction; the water in the tubes co necting the drums ascending to the steam drum, deliv this mixture of water and steam there, whereupon t steam separates from the water, and after traveling t space of 5 feet from the water level to the top of t drum, escapes, and the water which is left behind ent the circulating pipe and is carried down to the m drum and again arises with its mixture of steam.

The boiler rests upon four iron brackets riveted lower, or mud drum, supported upon four piers of foundation, the entire structure standing without c tact with the brickwork, allowing the boiler freedom expansion without in any way straining the brick setti In all places where pipe connections are made to boilers through the walls, they are encased in exp sion boxes.

Owing to the fact that the gases escape through central opening in the upper drum, the upper tube sh has a circular opening in its center, leaving a cen open space between the tubes, which gradually narro to the bottom tube sheet. Advantage is taken of t space, which is in the form of an inverted cone, to troduce deflecting plates, which in connection with c responding baffles or offsets in the brick casing ca the gases to be alternately thrown out and in through the whole heating surface, which extracts from th gases their heat, until they come to very nearly the t perature of the water contained in the boiler.



The Cahall Vertical Water Tube Boiler.
Fig. 90.

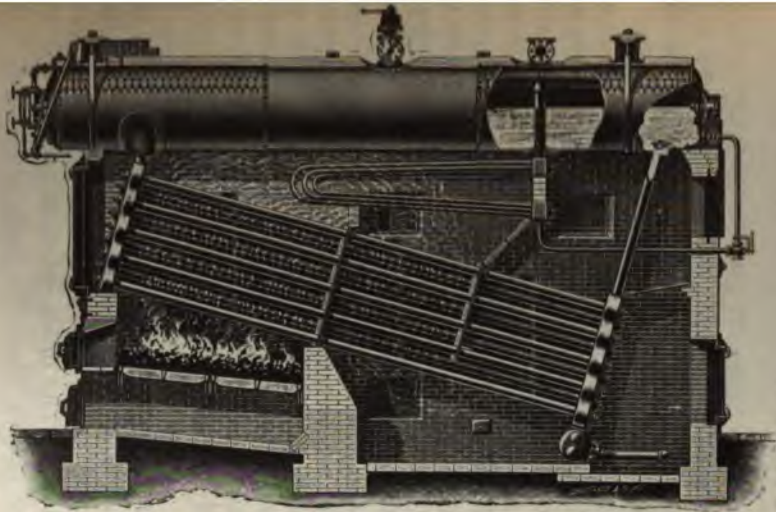
THE BABCOCK AND WILCOX WATER TUBE BOILER.

Construction.—This boiler as shown in Fig. 91 is composed of lap-welded wrought iron tubes, placed in an inclined position and connected with each other, and with a horizontal steam and water drum, by vertical passages at each end, while a mud drum is connected to the rear and lowest point in the boiler.

The end connections are in one piece for each vertical row of tubes, and are of such form that the tubes are "staggered" (or so placed that each row comes over the spaces in the previous row). The holes are accurately sized, made tapering, and the tubes fixed therein by an expander. The sections thus formed are connected with the drum, and with the mud drum also by short tubes expanded into bored holes, doing away with all bolts, and leaving a clear passage way between the several parts. The openings for cleaning opposite the end of each tube are closed by handhole plates, the joints of which are made in the most thorough manner, by milling the surfaces to accurate metallic contact, and are held in place by wrought iron forged clamps and bolts. They are tested and made tight under a hydrostatic pressure of 300 pounds per square inch, **iron to iron, and without rubber packing, or other perishable substances.**

The steam and water drums are made of flange iron or steel, of extra thickness, and double riveted. The mud drums are of cast iron, as the best material to withstand corrosion, and are provided with ample means for cleaning.

Erection.—In erecting this boiler, it is suspended entirely independent of the brickwork, from wrought iron girders resting on iron columns. This avoids any straining of the boiler from unequal expansion between it and



The Babcock and Willcox Water Tube Boiler.
Fig. 91.

its enclosing walls, and permits the brickwork to be repaired or removed, if necessary, without in any way disturbing the boiler.

THE STIRLING WATER TUBE BOILER.

The Stirling Boiler (Figs. 15 and 54) consist of three upper or steam drums, each connected by a number of tubes (called a "bank") to a lower or mud drum. Suitably disposed firetile baffles between the banks direct the gases into their proper course. Shorter tubes connect the steam spaces of all upper drums, also water spaces of front and middle drums. The boiler is supported on a structural steel frame work, around which is built a brick setting whose only office is to provide furnace space, and serve as a housing to confine the heat.

The Drums vary from 36 to 54 inches in diameter and are made of the best open hearth flange steel. The plates extend the entire distance between heads, hence there are **no circular seams.** The longitudinal seams—which are double or triple riveted according to the working pressure to be carried—are so placed that they are not exposed to high temperature. The drum heads are hydraulically dished to proper radius; each drum is provided with one manhole, and the manhole plate and arch bars are of wrought steel; four manhole plates, which can be removed in a few minutes, give access to the entire interior of the boiler, and expose every tube end, rivet, and joint. The drum interiors are perfectly clear; there are no baffles, stays, tie rods, mud pipes, or other obstructions in them.

The tubes are lap-welded mild steel. They are slightly curved at the ends to permit them to enter the drums normally and to provide for free expansion of the boiler when at work. The tubes are expanded di-

reamed holes in tube sheets of the drums. end is visible and accessible.

ramework.—As the entire weight of boiler s is supported on the steel framework, crack-etting due to unequal settlements is obviated, cking is needed when the brickwork has to

and Course of Gases.—The baffle walls rest on the tubes, and guide the course of the the front bank, down the middle and up the hus bringing them into such intimate contact iler surface that the heat is quickly and thor-acted from them. The baffles are made of gular firetile.

Circulation.—The path of the circulation in is as follows: The water is fed into upper passes down the rear bank of tubes to the , thence up the front bank to forward steam e the steam formed during passage up the lisengages and passes through the upper row bes into the middle drum, while the **solid** s through the lower cross tubes into middle down the middle bank to lower drum, from again drawn up the front bank to retrace its rse until it is finally evaporated. The steam n the rear bank passes through cross tubes er drum.

mperature of gases in contact with the tubes ily be greatest at the bottom of the front bank, lly decrease as the gases proceed along their the breeching. Obviously then the velocity rculation and quantity of steam generated will num in the front bank; in the rear bank there irculation downward equal to the quantity of orated in the other two banks.

SPECIFICATIONS FOR A 20 HORSE POWER VERTICAL SUBMERGER FLUE BOILER.

This boiler shall be built in accordance with the following specifications:

Dimensions:

Diameter of boiler, 42 inches.
Height of boiler, 96 inches.
Height of fire box, 30 inches.
Number of tubes, 85.
Diameter of tubes, 2 inches.
Length of tubes, 48 inches.
Thickness of shell, 1/4 inch.
Thickness of fire box, 5/16 inch.
Thickness of heads, 3/8 inch.
Thickness of cone, 5/16 inch.
Diameter of rivets, 11/16 inch.
Diameter of rivet holes, 3/4 inch.
Pitch of rivets, 1 inch.

Steel Plates.—All plates used in the construction of ie boiler shall be of the best open hearth steel having tensile strength of from 55,000 to 60,000 pounds per uare inch of section, to show an elongation of not less ian 25 per cent in a parallel test piece 8 inches long, companied by a reduction in area of not less than 50 r cent and to endure a bending of 180 degrees flat upon self without fracture, both before and after being ought to a red heat and quenched.

The maker's name, brand and tensile strength to be amped on each sheet, and plainly visible for inspection.

Fittings.—This boiler is to be equipped with a full t of fixtures and fittings, which includes base, grates, ors, glass water gauge, steam gauge and siphon, gauge

cocks, safety valve, check valve, stop valve, blow-off valve and smoke stack. Boiler to have hand holes above flue sheet and at bottom of fire box for cleaning out.

SPECIFICATIONS FOR A 25 HORSE POWER LOCOMOTIVE TYPE OF BOILER.

The contractor will furnish and deliver at ....,... one horizontal portable, water front, open bottom steam boiler of 25 horse power capacity at 100 pounds working pressure in accordance with these specifications.

Workmanship.—The material used in the construction of this completed apparatus shall be new and unused and the best of their respective kinds when not otherwise specifically mentioned. This boiler shall be not less than 25 horse power and not less than the following dimensions:

Dimensions:

Diameter in inches, 36 inches.
Length of fire box, 52 inches.
Height of fire box, 38 inches.
Width of fire box, 30 inches.
No. of 3-inch tubes, 34.
Length of tubes in inches, 96 inches.
Thickness of shell, ¼ inch.
Thickness of outside of fire box, 5/16 inch.
Thickness of furnace plate, 5/16 inch.
Thickness of tube sheets and heads, ⅜ inch.
Size of dome, 18x18 inches.
Size of safety valve, 2 inches.
Size of blow-off, ¼ inch.
Size of check and stop valve, 1 inch.
Diameter of stack, 18 inches.

Steel Plates.—All plates and heads used in the construction of this boiler shall be of the best quality of open hearth steel having a tensile strength of from 55,000 to 60,000 pounds per square inch of section, to show an elongation of not less than 25 per cent in a parallel test piece 8 inches long, accompanied by a reduction in area of not less than 50 per cent, and to endure bending 180 degrees flat upon itself without fracture both before and after being brought to a red heat and quenched.

The maker's name, brand and tensile strength to be stamped on each sheet and plainly visible for inspection.

Fittings.—This boiler is to be equipped with a full set of fixture and fittings including injector and smoke stack hinged complete, ready for steaming, also set of firing tools. The contractor shall also furnish a certificate of inspection from any good insurance company, and also from the Inspector of Boilers and Elevators of ....

Running Gear.—This boiler shall be mounted on running gear with iron wheels, single and double trees and tongue well built and substantially the same as shown on drawings accompanying these specifications.

SPECIFICATIONS FOR A HORIZONTAL RETURN TUBULAR BOILER WITH DOWN DRAFT FURNACE.

1. **Number and Type.**—There will be one boiler of the horizontal return tubular pattern, 66 inches diameter, 18 feet long. Thickness of shell, 3/8 inch; heads, 1/2 inch. Shell to be built of two plates, each forming a complete ring. Longitudinal seams well removed from the fire, and alternated to avoid a continuous line. A smoke box extension extending above tubes will be

bolted to the front end, to be of steel, 18 inches lon .134 inch thick (No. 10 B. W. G.).

2. **Dome.**—Shell to have steam dome as shown, 3 inches diameter, 36 inches high; measured on side. T have bumped head. Material, steel, 5-16 inch thic Shell to be well reinforced under dome, and to hav three 3-inch openings through shell for steam suppl and two ¼-inch drain openings.

3. **Steel Plates.**—Shells, heads, and domes to b made of flange steel, having an ultimate tensile strengt of not less than 60,000 nor more than 65,000 pounds pe square inch elastic limit one-half the ultimate; elonga tion in 8 inches not less than 27 per cent; maximu phosphorus, 0.06 per cent; maximum sulphur, 0.04 pe cent. The material is to stand bending double on itse without fracture, both cold and after being brought to flanging heat and quenched with water of 70 degre temperature. Plates to be free from surface defects, homogeneous and uniform quality and thickness, workmanlike finish, and stamped with the maker's nan and tensile strength. These stamps are to be preserv for identification, and are to be so placed as to be visib from outside of boiler. Edges of plates to be planed proper bevel.

4. **Riveting Etc.**—Longitudinal seams to be tri riveted butt joints of at least 87.5 per cent efficien with inner and outer covering straps. Girth seams si gle riveted. Vertical and base seams of dome dou lap riveted. Rivets to be of good charcoal iron, or extra soft steel, of 52,000 to 62,000 pounds tens strength and 38,000 pounds shearing strength. They to be capable of bending double on themselves, wi fracture, both cold and after being heated to cherry and quenched. They will have hemi-spherical or co

ds, and be of sufficient length to make the formed ds equal in strength to the pressed heads, and must the rivet holes completely. Heads to be concentric h rivets. Rivet holes to be punched 3/32-inch small l then reamed out. Both before and after sheets are embled the burrs and sharp edges of rivet holes are be removed by reaming and countersinking. The proper use of the drift pin is prohibited. Defective eting must be promptly cut out and satisfactorily re-ced. The design of seams, dimensions of rivets, pitch, cing, and lap, as well as other details not specifically cribed herein, are to be in accordance with the best gineering practice.

5. **Bracing.**—Heads to be well stayed by a suffi-nt number of McGregor, Lukens, or Huston crow foot ces, made of single pieces of open hearth homo-neous flange plate, bent to shape in one heat without eld, and then annealed.

6. **Tubes.**—Boiler to have 72 tubes, 3½-inch ex-nal diameter, 18 feet long, not less than .12 inches ick (No. 11 B. W. G.), accurately and uniformly aced, and neatly expanded into heads. Copper fer-les to be used in rear heads. Tubes to be of best soft teel, lap welded or drawn, and ends annealed before tting. The tube holes are either to be drilled or nched out, and then neatly reamed. Corners to be amfered off, and heads annealed after punching and before reaming.

7. **Working Pressure.**—The boiler is intended to work regularly at approximately 115 pounds. With nace attached, the boiler will be tested by the con-tractor after erection, in the presence of the engineer, under 175 pounds hydrostatic pressure, and be made ght under same. All parts to be proportioned for a

factor of safety of not less than five on minimum sections.

8. **Flanges and Caulking.**—All flanges are to be turned at a good red heat, to radii of not less than 2 inches, and must be free from hammer marks and other flaws. All plates to be annealed after flanging. The caulking is to be done in best manner, with round nose tools. All accessible seams to be caulked on both sides.

9. **Man-Holes.**—There will be two man-holes in each shell, 10x16 inches or 11x14 inches, one in rear head above tubes, or in top of shell, and the other in front head under tubes. They will be of the Eclipse pattern, or its equivalent, complete with grooved lids, pressed steel arches, bolts, nuts, and grooved lead gaskets.

10. **Openings.**—The boiler will have one 5-inch opening on side of dome for main steam outlet; one 3½-inch for safety valve; two 1¼-inch for water column; one 1½-inch for feed; one 2-inch for auxiliary steam service; one 3-inch for gravity return and blow-off. The 5 and 3½-inch openings to have cast or pressed steel nozzles well riveted to shells, with flanges properly finished, the former for a standard 5-inch pipe flange, and the latter for flange of safety valve. Two and 3-inch openings to be reinforced by flanges, well riveted and threaded.

11. **Fittings and Fixtures.**—Furnish with boiler: One 3½-inch nickel seated flanged pop safety valve, set to blow at 115 pounds, one 1½-inch check valve, one 1½-inch stop valve, one 2-inch Homestead or equivalent blow-off cock, connected to 3-inch line by reducing T. Other valves to be of approved make, and all to be of best composition steam metal. One bronze mounted water column, not less than 4-inch internal diameter,

with 1¼-inch unvalved connection to shell, made up with tees, crosses, and plugs, to permit cleaning. To be complete with necessary valves, guards, and three try cocks. Valves and cocks to be operated from floor level by chains. One 8-inch dial, brass case, steam gauge, reading to 200 pounds, with syphon of approved form, drain and coupling. Attach 1½-inch feed pipe 16 feet long to front head inside of boiler, with elbow looking downward at rear end, properly supported. Front end to have T with one end closed by brass plug. Furnish all pipe and fittings necessary, and connect above named valves and fittings to boiler. Provide side and rear angles shown on plans for brick work joints, and attach same rigidly to boilers. Furnish additional angle, as shown, for rear arch support for brick mason, with anchor bolts, to go through rear wall.

12. **Casting, Etc.**—Provide one ornamental full flush front with suitable doors, opening to right and left. Fire and ash doors to be fastened with independent frames, bolted on, and to have registers. Fire doors of Pickle or equivalent pattern. Provide all necessary liners, plates, arches, jambs, rods, nuts, washers, and floor plates. Front to be lettered:

....

Furnish one clean out door, with frame, complete, with register, or peep hole. All doors to be close fitting and air tight. Furnish stack plate for chimney, with close fitting swing damper and handle, counterweighted and provide with chain and hook plate located on front near fire doors. Furnish skeleton arches for fire brick at rear-head. Furnish two 10 foot wall binding bars with rods, plates, washers, and nuts, as required by plan. Castings to be smooth, close grained, sound, tough, of

true forms and dimensions, free from blow holes, scabs, and other defects.

13. **Furnace.**—Provide boiler with an app form of down draft furnace. The front will hav doors opening across full width of furnace, to be Pickle, or equivalent pattern. Upper grates 4½ long, to consist of a single row of 2½-inch special grade steel tubing. Front drum 10 inches diamet high grade steel tubing with hand-hole; rear dr inches diameter, of fire box steel, with man-hole plete. Provide all necessary circulating pipes, blov and valves. Lower grates 5 feet long, of the or pattern, with bearing plates. Fittings, steel.

14. **Deflectors..**—Front head to be provided hinged removable deflecting dampers over upper of tubes, as shown on plan. These dampers to be of 3/16-inch steel, with extension at top of each supported in ½-inch holes in smoke box extensi both sides.

15. **Smoke Flue.**—Furnish and erect one s flue, of dimensions and shape shown on plan. Ma sheet steel, .134-inch thick (No. 10 B. W. G.). end shaped to fit stack plate, rear end to fit entranc brick chimney base. Provide suitable hanger to su flue near its center.

16. **Supports.**—The boiler will be hung from steel channels each 10 inches deep, weighing no than 15 pounds per foot, and of full length, restin steel columns. Side lugs to be of steel plate car shaped and well riveted to shell. Each lug to be d accurately and in line to receive the supporting which—with channels, links, columns, plates, nuts washers—are to be furnished by this contractor, a tailed on plans.

17. **Painting.**—The boiler, supports, smoke flue, re front, fire, ash and cleaning doors, and other metallic rts—except grates—shall, after being cleaned and in-cted, receive one coat good black asphaltum, before pment, and another after erection and completion.

18. **Foundation.**—To be of dimensions shown on ns, of concrete made of approved Portland cement, xed one part cement to three of clean sharp river sand, l worked up with five parts clean crushed macadam, sizes that will pass through a 1½-inch ring, and well ted. When dumped pack down thoroughly with a vy maul, until the water works to the surface. Ash under and in front of boiler to have good granitoid ving. Cut and repair present boiler room floor as y be necessary, including new cement pit in front of ler, as shown on plan.

19. **Brick Work.**—Furnace walls to be of hard red ck, carried up together, plumb, straight, and level cing of selected smooth hard red brick. Cover top of l with brick on edge, well plastered. Every fifth se headers. Carry up smoke outlet ready to receive k plate. Wall in all necessary rods, plates, doors, es, etc. Joints to be flushed full, and neatly trowel-l. Mortar to be of good sharp sand and fresh lime, barrel Portland cement added for every four thou-d brick. All walls to have air spaces. Cut and re-brick work in south face of chimney to receive e flue. Move present clean out door in base of ey to south face, with necessary brick work.

20. **Fire Brick.**—All parts of the furnace exposed to ame to be lined with good St. Louis fire brick. l in dry milled fire clay, and laid with very thin . Headers every fifth course. All brick in front

faces of bridge walls to be headers. Use jamb, wedge other shaped brick wherever directed.

21. **Erection.**—This contractor will deliver all m terial herein provided for in ...., a will erect same in position ready for external pipe co nections. He will place in permanent position, ready use, all foundations, brick work, fixtures, fittings, e belonging to the boiler. He will take all necess measurements and verify all data on the ground.

22. **Inspection and Insurance.**—The contractor w furnish the purchaser with a Certificate of Inspection a Policy of Insurance for $500.00 for one year, in so good insurance company. The contractor will arran for all necessary tests, inspections, etc., required by s insurance company, and by the ordinances of the C of ...., and will deliver to the purchas without extra charge, certificates of such tests, etc., thorizing the purchaser to operate the boiler under desired conditions.

SPECIFICATIONS FOR A 100 HORSE POW WATER TUBE BOILER, INCLUDING SPE FICATIONS FOR A DOWN DRAFT FURNA AND SMOKE STACK.

Number, Type and Size.—There shall be one bo of the horizontal inclined water tube type, rated at horse power; the term horse power being understood mean 30 pounds of water evaporated per hour from fe water having a temperature of 100 degrees Fahren into steam at 70 pounds gauge pressure.

General Description.—The boiler in all its m parts is to be composed of plate steel. It is to con of two water legs of equal size, approximately rectan

ape, joined together by means of a series of ver- l horizontal staggered rows of tubes, and one l circulating steam and water drum... The and tubes are to be made parallel to each other, water legs made perpendicular to both. When erected, same must incline towards the rear a of 1-inch per lineal foot.

es.—All plates used in the construction of this e to be of the best open hearth homogeneous eel, having a tensile strength of 60,000 pounds re inch of section. These plates are to be plainly with the name of the manufacturer, the tensile and the quality; said stamps to be so located easily visible after the boiler has been com-

thicknesses required for these plates are given ie various paragraphs relating to the specific the boiler herein described.

es.—This boiler is to contain sixty-one (61) ch having an outside diameter of 3½ inches, and of 16 feet. Each tube is to be of the best lap- juality, standard gauge in thickness, and made The ends of all tubes are to be thoroughly ex- nto the tube plates of the water legs.

distance from center to center horizontally of s is to be 7¼ inches, and the distance vertically 5 inches, except that between the bottom row next row above, which is to be 8½ inches, so as it the introduction of a course of tile on top of er row. The boiler is to be made eight rows d eight rows high.

ater Legs.—This boiler is to be furnished with ater legs, each consisting of a tube plate, and a ole plate joined together by means of a strap riv-

eted around the outside. These plates are to be so ranged as to leave a clear space of 10 inches betw them on the inside.

The hand hole plate of each water leg is to be nished with a series of oval hand holes, each measu $3\frac{5}{8}$ inches in size, and furnished with a heavy cast cover plate, one arch, one bolt and a lead gasket. hand hole is located directly in front of each end of tube so as to permit easy access for cleaning.

The water leg plates are to be thoroughly s bolted together by means of hollow stays, each hav a minimum outside diameter of 1 9/16 inches, space distance of $7\frac{1}{4}$ inches center to center horizontall inches center to center vertically.

All seams around the perimeters of the water are to be furnished with single riveted lap joints rivets spaced a distance of 2 inches center to center, having a diameter, after being driven, of 13/16 inch. the throats where the legs are attached to the circula drums, double riveted lap joints are used.

Circulating Drum.—This boiler to be furnished one drum for permitting the circulation of the w from the front water leg to the rear water leg, and affording a steam space in the upper half. This d is to have an internal diameter of 36 inches, and a len of shell of 19 feet 3 inches. The heads of this d are to be dished to a radius equal to the diameter of shell, and the rear head is to be furnished with a hole of the Hercules pattern approximately 10x16 inc in size. At the forward end of the drum is to be loc a baffle plate extending towards the rear a distanc about 6 feet and located directly underneath the st opening, so as to prevent any entrainment in the A sufficient opening is to be left between the top

f the baffle plate and the top of the shell to give an rea equal to at least one and one-half times the area of e steam opening. For details of steam basket, see aragraph attached to back of specification, reading team Basket.

This drum is to be furnished with a cast steel tee nge having an internal diameter of 5 inches, and riveted to the top of the shell, a distance of 24 inches been the center of the same and the front edge of the ell plate. This tee is to be furnished with a flanged nection at the top for the attachment of 3½-inch pop fety valve.

A 2-inch feed pipe connection is to enter the front nd of this drum as near the bottom as possible, extendg towards the rear, and arranged to discharge directly er the opening leading to the rear water leg. The d pipe is to discharge into an oval mud drum deibed in the paragraph entitled Mud Drum and atched to the back of this specification.

The shell plate of this circulating drum is to be cut ay at the points where it joins to the water legs; this ning to be reinforced by means of two plate steel at stays made of ½-inch flange steel thoroughly rivd to the same.

All shell plates are to have a thickness of ⅜ inch, the heads a thickness of ½ inch.

The circumferential seams are to be furnished with e riveted lap joints, and the longitudinal seams with e riveted lap joints. The details of these joints are in the blue print hereto attached.

ck Stays.—Six (6) buck stays are to be furnished is boiler. These buck stays are to be of the chan-ttern made in accordance with a detailed sket nished by the ....tie

.... round iron, provided with all the necessary nuts and washers, and of sufficient length to extend entirely across the width of the setting, are to be furnished with the buck stays.

Trimmings.—This boiler is to be furnished with one 3½ inch nickel seated pop safety valve ...... set to blow at 110 pounds per square inch, one 2-inch feed valve, one 2-inch check valve, two 1¼-inch asbestos-packed blow-off cocks, one water column fitted with 1½-inch pipe connections to boiler, three ¾-inch Pittsburg gauge cocks, one ¾-inch glass water gauge with brass valves and guard rods, and one 10-inch steam gauge with syphon. Gauge cocks to be fitted with chains and handles of sufficient length so they can be operated from floor.

Castings.—This boiler is to be furnished with one special type water tube boiler front, a sufficient number of cast iron grate bars for covering a width of 54½ inches, and a length of 54 inches, one back grate bearing bar, two (2) soot doors and frames, one set of back wall supporting plates, and one set of saddles for locating underneath the rear water leg.

Boiler Support.—The front water leg is intended to be supported by means of cast iron columns located in the lower section of the boiler front, and the rear water leg by means of a low supporting wall.

Tube Tile.—A full set of fire clay tube tile is to be furnished for covering the top and the bottom rows of tubes.

Tile Bars.—Two tile bars made of 1¼-inch square iron are to be furnished for this circulating drum. These bars are to be held in place by means of wrought iron hangers located at intervals of four feet, and securely

lted to the shell; the purpose of the bars being to support the ends of the tiling, closing in around the drum.

Fire Tools.—This boiler is to be furnished with a t of fire tools, consisting of S-wrench, one ½-inch soot ower, furnished with about 10 feet of steam hose, connection for the soot blower is to be furnished at the front d back ends of the boiler, and one 3½-inch tube raper, with handle.

Smoke Hood.—A smoke hood made of No. 8 gauge eel is to be furnished and located on top of the boiler. his is to be approximately 4 feet in height, and designed in accordance with detailed drawing to be furnished by .... The top is to be rounded and furnished with a band riveted a distance of about 4 inches below the top edge for supporting 32-inch diameter smoke stack. Hood to be reinforced by angle iron and small door to be located near bottom for cleaning. Put in damper No. 8 steel and furnish lever and chain so as to permit operation from floor.

Smoke Stack.—One smoke stack is to be furnished with this boiler having a diameter of 32 inches, and a height of 80 feet. This stack is to be fitted with a ⅜x2½-inch band riveted around outside edge at top, and a ⅜x3½-inch band riveted around bottom edge on outside. Fit the top band with two paint rings made of ¾-inch round iron, and about 5 inches in length for attachment of painters' rigging.

There are to be riveted to the inside of this stack at the proper locations, two bands, each made of No. 10 gauge steel, and having a width of 12 inches for reinforcing the stack at the points where the guy bolts are to come. Two sets, each consisting of four eye bolts are to be fitted to the stack at the points where these bands are located, for the attachment of ⅜-inch galvanized

strand guys. The eye bolts are to be fitted with clevises so that the strand can be fastened thereto. Two coats of black asphaltum paint are to be applied to stack; one when same is in shop, and the other after erection. A casing made of No. 12 sheet steel and of sufficient diameter to leave a clear space of 12 inches all around the smoke stack is to be furnished. This to be of sufficient height to extend above the roof a distance of about 2 inches. A weather apron to be bolted around stack, having a width of about 18 inches.

Testing and Inspection.—A hydrostatic pressure of 165 pounds per square inch is to be applied to this boiler before it leaves our works, and a certificate of said test, together with a policy of insurance for $500.00 for one year, issued by any reliable boiler insurance company, is to be furnished.

Steam Basket.—A perforated basket is to be furnished and located directly beneath the steam opening, as an additional precaution for obtaining dry steam. This is to be provided with a sufficient number of ½-inch diameter holes to give an area equal to at least twice that of the steam opening.

Mud Drum.—An oval mud drum measuring 10 feet in length, 14 inches in width, 8½ inches in height, and made of five sections, each about 2 feet in length, is to be located near the bottom of the shell of the circulating drum. This is to be made of No. 12 steel, with the exception of the back head, which is to be made of 3/16-inch steel. The back head is to be fitted with a small hand hole provided with the necessary plate and arch. A 1¼-inch blow-off pipe connection is also to be screwed in this back head as close to the bottom as possible and extending out through the head of the circulating drum.

An opening in the shell of the mud drum is to be located at the front end, measuring about 14 inches in width by 15 inches in length. The oval drum is to be suspended from the inside of the shell of the circulating drum by means of three straps, located at equal intervals along the length of the same.

Water Column.—The water column is to be connected to the bottom of the shell of the circulating drum at the front end, in accordance with a sketch to be furnished.

Down Draft Furnace.—One down draft smokeless furnace is to be attached to the boiler. This is to consist of a front and a rear manifold joined together by means of a single row of extra heavy tubes, each having an internal diameter of 2½ inches, and a length as measured between the shells of the manifold of 4 feet. These tubes are to be spaced a distance of 5.45 inch center to center, thus making a total of ten tubes to form the grate. The front manifold is to be connected to the boiler by means of two vertical 4-inch pipes, one on each side of the furnace, and connecting to the bottom of the front water leg on the back side by means of special cast steel tees. The rear manifold is to be connected to the circulating drum of the boiler by means of a 4-inch pipe located on each side. This pipe is to be bent; the use of ells to form the bend not being permitted. A collar made of No. 10 gauge steel is to be furnished for the outside end of the rear manifold. This collar is to have a length of 9 inches, and no rivets are to be used in the same. The plates being merely rolled up to size and the edges butted.

The blow-off connections for both the front and the rear manifolds are to be 1½-inch diameter; we furnishing the necessary nipples and valves, but we do not connect the same up with the blow-off tank.

FORM OF SPECIFICATIONS FOR A SAFET WATER TUBE BOILER.

Number, Type and Size.—There shall be ...... boiler.. of the horizontal inclined water tube type, rat at ...... horse power, the term horse power being u derstood to mean 30 pounds of water evaporated p hour from feed-water having a temperature of 100 c grees Fahrenheit into steam at 70 pounds gauge pr sure.

General Description.—The boiler in all its ma parts to be composed of plate steel. It is to consist two water legs of equal size, approximately rectangu in shape, joined together by means of a series of v tical and horizontal staggered rows of tubes, and ... overhead circulating steam and water drum... T drum.. and tubes are to be made parallel to each oth and the water legs made perpendicular to both. Wh boiler is erected, same must incline towards the r a distance of 1 inch per lineal foot.

Plates.—All plates used in the construction ...... boilers .. are to be of the best open hearth hor geneous flange steel, having a tensile strength of 60,(pounds per square inch of section. These plates are be plainly stamped with the name of the manufactu the tensile strength and the quality said stamps to be lócated as to be easily visible after the boiler.. has b completed.

The thickness required for these plates are gi under the various paragraphs relating to the spe parts of the boiler herein described.

Tubes.—...... boiler is to contain .... t each having an outside diameter of 3½ inches, a length of ...... feet. Each tube is to be of the

lap-welded quality standard gauge in thickness, and made of .... The ends of all tubes are to be thoroughly expanded into the tube plates of the water legs.

The distance from center to center horizontally of the tubes is to be 7¼ inches, and the distance vertically is to be 5 inches, except that between the bottom row and the next row above, which is to be 8½ inches, so as to permit the introduction of a course of tile on top of the lower row.

Water Legs.—...... boiler is to be furnished with two water legs, each consisting of a tube plate, and a hand hole plate joined together by means of a strap riveted around the outside. These plates are to be so arranged as to leave a clear space of 10 inches between them on the inside.

The hand hole plate of each water leg is to be furnished with a series of oval hand holes, each measuring 3⅝ inches by 4¾ inches in size, and furnished with a heavy cast iron cover plate, one four-prong arch, one bolt and a lead gasket. A hand hole is located directly in front of each end of each tube so as to permit easy access for cleaning.

The water leg plates are to be thoroughly stay-bolted together by means of hollow stays, each having a minimum outside diameter of 1 9-16 inches, spaced a distance of 7¼ inches center to center horizontally, 5 inches center to center vertically.

Castings.—...... boiler is to be furnished with one standard type water tube boiler front, a sufficient number of cast iron grate bars for covering a width of ...... inches, and a length of ...... inches, one back grate bearing bar, two (2) soot doors and frames, one set of

back wall supporting plates, and one set of saddles for locating underneath the rear water leg.

Boiler Supports.—The front water leg is intended to be supported by means of cast iron columns located in the lower section of the boiler front, and the rear water leg by means of a low supporting wall.

Tube Tile.—A full set of special ...... fire clay tube tile is to be furnished for covering the top and the bottom rows of tubes.

Tile Bars.—Two tile bars made of $1\frac{1}{4}$-inch square iron are to be furnished for ...... circulating drum. These bars are to be held in place by means of wrought iron hangers located at intervals of four feet, and securely bolted to the shell; the purpose of the bars being to support the ends of the tiling, closing in around the drum.

...... drum is to be furnished with a ...... flange having an internal diameter of .... inches, and riveted to the top of the shell, a distance of .... inches between the center of the same and the front edge of the shell plate.

A ...... inch feed pipe connection is to enter the front head of ...... drum as near the bottom as possible, extending towards the rear, and arranged to discharge directly over the o[illegible] .cading to the rear water leg.

All seams around the perimeters of the water legs are to be furnished with single riveted lap joints with rivets spaced a distance of 2 inches center to center, and having a diameter, after being driven, of 13/16 inch. At the throats, where the legs are attached to the circulating drums, double riveted lap joints are used.

Circulating Drum.—...... boiler to be furnished with ...... drum.. for permitting the circulation of

from the front water leg to the rear water leg, affording a steam space in the upper half. um is to have an internal diameter of ...... d a length of shell of ...... feet ...... inches. s of ...... drum.. are to be dished to a radius he diameter of the shell, and the rear head is ished with a man hole of the Hercules pattern ately 10x16 inches in size. At the forward end drum is to be located a baffle plate extending he rear a distance of about 6 feet and located nderneath the steam opening, so as to prevent inment in the steam. A sufficient opening is between the top edge of the baffle plate and f the shell to give an area equal to at least one-half times the area of the steam opening.

mings.—...... boiler is to be furnished with .. inch pop safety valve ...... set to blow pounds per square inch, one ...... feed valve, .. check valve, ... 1¼-inch asbestos-packed cocks, one water column fitted with 1½-inch nections to boiler, three ¾-inch gauge cocks, nch glass water gauge with brass valves and ds, and one ...... steam gauge with syphon.

shell plate of ...... circulating drum is to be y at the points where it joins to the water legs; ning to be reinforced by means of ...... plate at stays made of ½-inch flange steel thoroughly d to the same.

ll shell plates are to have a thickness of ...... d the heads a thickness of ...... inch.

e circumferential seams are to be furnished with eted lap joints, and the longitudinal seams with veted ...... joints.

Buck Stays.—...... ( ) buck stays are to be furnished with ...... boiler.. Each buck stay is to consist of two rolled steel angles, 3½ inches by 3½ inches by ⅜ inch in size, bolted together back to back at intervals of about three feet and separated by means of thimbles placed on the outside of the bolts, a distance of 1¼ inches throughout the entire length. ...... tie rods made of ...... round iron, provided with all the necessary nuts and washers, and of sufficient length to extend entirely across the width of the setting, are to be furnished with the buck stays.

Fire Tools.—...... boiler.. ...... to be furnished with a set of fire tools, consisting of a scoop, hoe, rake and slice bar. There is also to be furnished one 3½-inch tube scraper with handle.

Smoke Stack.—...... smoke stack is to be furnished with ...... boiler.. having a diameter of ...... inches, and a height of ...... feet ......

Testing and Inspection.—A hydrostatic pressure of ...... pounds per square inch is to be applied to ...... boiler before it leaves the works, and a certificate of said test, together with a policy of insurance for $..... for one year, issued by any reliable boiler insurance company, is to be furnished.

FORM OF SPECIFICATIONS FOR A HORIZONTAL TUBULAR BOILER.

Number, Type and Size.—There shall be .... boiler ...... of the Horizontal Tubular Type, each having a diameter of ...... inches and a length, as measured from out to out of heads, of ...... feet ...... inches.

Tubes, Arrangements, Etc.—...... boiler is to contain .... tubes, each having an outside

ter of ...... inches and a length of ...... feet. tube is to be of the best lap-welded quality, stand-auge in thickness and made of .... All are to be thoroughly expanded into the tube holes heads, and after this is done the ends are to be beaded over by means of round-nosed tools, by pneumatic pressure. The tubes are to be ar-d in vertical and horizontal rows, with a clear space inch between them, vertically and horizontally, the central vertical space, where a distance of two shall be allowed.

lates, Quality, Thickness, Etc.—All plates used in ell of ...... boiler.. are to be made of the best ....steel, having a tensile strength less than 60,000 pounds per square inch, and a ess of ...... The heads are to be made of the pen hearth homogeneous flange steel, of the same strength as that mentioned for the shell plates ving a thickness of ......

ll plates are to be plainly stamped with the name manufacturer, the tensile strength and the quality, amps to be so located as to be easily visible after iler .... been completed.

iveting.—The longitudinal seams are to be fur-l with ...... riveted ...... joints, with all rivets anged as to come well above the fire line.

racing.—The boiler heads are to be braced by of weldless steel crow-foot braces, having a diam-f ...... inches, so as to be of equal strength as the shell.

ry Pipe.—A dry pipe is to be located on the in-of ...... boiler shell and is to be connected to the steam opening by means of a special tee, located center. This dry pipe is to be closed at both ends

and is to be furnished with a sufficient number of ½-inch diameter holes located on the upper side to give an area equal to twice that of the steam opening. Both ends are to be closed and a ¼-inch diameter drip hole is to be located on the bottom of the dry pipe near each end.

Man Holes.—A man hole of the Hercules pattern is to be located in the front head beneath the tubes, and another ....

Castings.—...... boiler.. to be furnished with a ......fire front of the .... pattern. .... boiler is to be furnished with a sufficient number of standard cast iron grate bars to cover a width of ...... inches and a length of ...... inches; one back grate bearing bar; one soot door and frame; ...... skeleton arch plates. ...... boiler.. to be furnished with ...... buck stays, provided with tie rods, nuts and washers.

Trimmings.—...... boiler is to be furnished with one ...... safety valve; one ...... blow-off valve; one ...... feed valve; one ...... check valve; one combination steam and water column, with .... pipe connections to boiler; three gauge cocks; one glass water gauge, with brass valves and guard rods; and one steam gauge, with syphon.

Breeching.—...............................

Smoke Stack.—One smoke stack is to be furnished for ...... boiler.. having a diameter of ...... inches and a height of ...... feet, made of ...... sheet steel, and furnished with ...... feet of ...... galvanized strand for guys.

Boiler Supports.—...........................

Testing and Inspection.—A hydrostatic pressure of ...... pounds per square inch is to be applied to ...... boiler before it leaves our works, and a certificate of

test, together with a policy of insurance for ...... me year, issued by any reliable boiler insurance many, is to be furnished.

M OF SPECIFICATION FOR INTERNAL URNACE BOILER OF ... HORSE POWER.

Generally.—The boiler is to be of ... horse power horse power to mean 34½ pounds of water evaped per hour from a feed water temperature of 212 ees Fahrenheit into steam at atmospheric pressure), in all respects properly proportioned for a steam sure of ... pounds per square inch.

Material.—The material from which the boiler is to constructed shall be of open hearth flange steel, 00 pounds tensile strength. In a parallel test piece, ches long, when tested to destruction, the elonga- shall not be less than 25 per cent, and the elastic t shall not be less than one-half the ultimate tensile ngth. A similar test piece, shall permit of its ends g bent cold in a parallel direction, about a curve, se inner radius shall not be more than the thickness he test piece. This test to be made without fracture my point.

The shell of the boiler to be ...... inches, inside meter, and ...... inches, in thickness. The distribu- n of the plates, and also of the rivets, of the various ts to be, as shown by the drawing.

The front and rear heads are to be ...... inches ick, and to have their circumferential flanges of such ameter, as to properly fit the shell. These flanges to e turned to an internal radius of not less than one ch. The flanges of the furnace openings, in both the ront and rear head, to be turned inward (in respect to

the boiler) and to the be of sufficient lengths for single rows of rivets. The furnace opening of the front head, should be ¼ of an inch greater in diameter, than the furnace opening of the rear heads, to permit of the easy insertion of the furnace into position.

Furnace.—The furnace to be of the Morrison suspension type, ... inches, inside diameter, by ...... feet, and ...... inches long, and ...... inches thick, having plain parts, at the front and rear ends, of sufficient length to be single riveted to the furnace opening flanges of the boiler heads.

Tubes.—The boiler will contain ...... tubes, ... inches outside diameter, spaced ...... inches centers, and located as shown on the drawing.

Back Connection.—The rear course of the boiler shell, is to extend about 2½ inches, beyond the flange of the rear head, and to it, is to be bolted an extension forming a back connection. This extension may be of ordinary "tank steel" of sufficient width to provide for a combustion chamber, having a clear depth of 30 inches. Riveted to the inside of this extension, at its outer end, is to be a ring of 2½x2½x5/16-inch angle, to which will be bolted a head of ordinary "tank steel," made in two pieces, joined together by bolts, as shown on the drawing. In the lower portion of this head, there is to be an opening surrounded by an angle iron ring, forming a door frame, 18 inches wide, by 15 inches high, to which will be fitted a suitable door, provided with latch, hinges and baffle plate. Across the head, there should be a stiffening angle bar.

The inside circumference of the combustion chamber, is to be lined with fire brick, placed on edge, forming a lining 4½ inches thick. This lining should extend circumferentially upward, to a point one inch above the

e upper row of tubes. The back of the com-
hamber should be lined with fire brick, 9 inches
his lining of the rear head, or back end, should
d to the same height as the circumferential
ıd the opening at the top bridged over by fire
s, about 5 inches thick. One end of the tiles
pon an angle bar, riveted to the back head of
r, the other end upon the rear lining of the

ts.—The rivet holes are to be either drilled,
ed 1/16 of an inch small, then reamed to requi-
No drifting of unfair holes will be permitted.
t holes, at the furnace ends, are to be counter-
the inside, and the rivets driven upon the in-
ıe furnace, leaving slightly spherical rivet heads.
boiler heads are to be braced with ......
bolts, ... inches diameter, upset at each end
. inches diameter, and threaded. They are to
ed to the heads, with outside hexagonal nuts,
with washers 8 inches in diameter, and of 6/10
ness of the boiler heads. Upon the inside, there
e suitable washers and nuts (of half thickness)
up tight against the head. If preferred, the
aces of the heads may be braced by means of
Gregor Solid Steel Braces, instead of the through
above described, in which case the braces are
f sufficient number, and so located, as to thor-
stay the heads.

n and Hand Hole Openings.—Upon the top of
ll, there is to be located an Eclipse Man Hole
ver, 10x16-inch opening, provided with the usual
and bolt. In the front head, below the tubes,
re to be located hand hole and man hole openings,
wn, fitted with suitable covers and guards. The

openings in the shell and heads are to be reinfc strengthening pieces, of unequal section to the which the holes are cut, and securely riveted or side of the boiler.

Front Connection.—The front connection, t the general design shown by the drawing, an made of sheet metal 3/16 of an inch thick, se the front head of the boiler, by 2¼x2¼ angles a bolts, to have an interior lining of metal, ⅛ of thick, spaced 1 inch asunder, by means of thimb its upper portion, it will be drawn to a suitabl and surrounded by a ring 2½x2½x¼ angle, to for the reception of a smoke stack, ... in diameter. The front of the connection is to vided with a door, fitted with forged hinges and for securing it in place. The door to be provid a lining, affording a 1-inch air space.

Furnace Doors, Etc.—The front of the furna be closed by a Morison Protector Furnace Fr Door, and below it, is to be fitted a sheet iron door, provided with two forged handles and means for holding it in position.

Grate and Bridge Wall.—There is to be a c bridge wall, topped with fire brick, placed in nace, in a suitable position to provide for a gr of ...... square feet. Midway between it and t plate, of the furnace front, is to be located, a bearer bar, the ends of which are to rest upon supports. The grate bars to be of cast iron, p with openings to suit the character of fuel to b Beneath the grate is to be an ash pan, formed of ordinary "tank steel," bent to shape, and extendi the bridge wall to front of furnace.

Fittings.—Upon the top of the shell, and about midway of the length of the front course, is to be located a cast iron flanged nozzle, ... inches diameter, so arranged as to provide at its upper flange for a ...... inch safety valve, and at its side, a flanged nozzle to be suitable for attaching a steam connection.

Extending into the boiler from this cast iron nozzle, there will be a short pipe nipple, fitted to a tee, from the longitudinal branches of which will extend a dry pipe ...... inches diameter, each branch of which will be about 3 feet long, perforated along its upper surface with holes, giving an area of about 2½ times the area of the steam pipe. Upon the side of the boiler will be located a feed pipe ...... inches diameter. It will be formed of a short nipple entering the shell, to which will be connected, by means of an elbow, a pipe ...... inches diameter extending about one-half the length of the boiler, having perforations along its lower surface, about twice the cross-sectional area of the pipe. This internal pipe will be located about the height of the top row of tubes, and parallel thereto, its extreme end being held in position by means of a suitable fastening. Located at the bottom of the shell, and at its extreme rear end will be provided an opening suitable for a ... inch diameter blow-off cock. The hole in the shell being reinforced by a pressed steel pipe flange riveted thereto.

Test.—Before leaving the place of manufacture, the boiler will be completely filled with water, slightly warmed, and subjected to a test pressure of ...... pounds per square inch, and to be tight at that pressure.

SPECIFICATIONS FOR LATEST IMPROVED DOWN DRAFT SMOKELESS FURNACES.

Manifolds.—The front and rear manifolds of these furnaces are made of special lap-welded steel tubing 8 inches in diameter, of the highest quality, made especially for the purpose. Thickness of metal in these manifolds ⅜ of an inch. Heads flanged and riveted in, hand plate in one end, thickness of heads ⅜-inch of open hearth flange steel. The rear drums have two special forged steel flanges riveted on for 5-inch pipe and the front drums have flanges for 4-inch pipe.

Connecting Tubes.—The grate tubes connecting the two manifolds are 2 inches in diameter and 2⅜ inches outside diameter, a double staggered row properly spaced. They are made of special cold drawn seamless steel tubing. The tubes are screwed into the rear manifold and expanded into the front manifolds. The length of the tubes are from 4 feet to 5½ feet according to the length of the boiler.

Brass Plugs.—In the front manifolds there are 2¼-inch brass plugs screwed in, one opposite each grate tube for inspection and washing, a panel being placed in the fire front fastened on with small lugs and screw bolts giving free access to these brass plugs. By loosening up the cap screws slightly the lug can be turned so that the panel can be readily removed and replaced.

Connections.—The connections between the furnace and boiler are made of extra heavy pipes with steel or semi-steel fittings, the front connections being 4 inches in diameter and the rear connections 5 inches in diameter. Where boiler is set with full flush fire front the front connections are made through the head of the boiler by means of 4-inch boiler tube being expanded

ead. Where the boiler is to be set with ¾ ront, these connections are made in the shell ront end. The rear connections are made by -inch extra heavy pipe from the rear mani- onnecting into the back head of the boiler in ner as the front connections when set with or ¾ arch front, except where space in rear vill not permit, in which case the connections in the upper quarter of the boiler directly rear manifold.

ronts.—Each furnace is supplied with a fire er of the full flush or three quarter arch pat- y be desired. These fronts are supplied with front bearing bars, Pickle patent fire doors, ary lower doors and ash pit doors.

furnaces can be attached to boilers already in s well as to new boilers, by making the neces- ge in fire fronts and removing and replacing k, and also providing for the necessary sup- e front end of the boiler, except where same is pported independent of the fire front.

The cost of equipping **new** boilers of 60-inch, 72-inch diameter, with **down draft** furnaces, var- $400 to $450. The cost of equipping **old** boilers liameters, from $600 to $700.

oom.—Such furnaces will increase **height** over raft furnaces about 18 inches.

power.—The addition of a down draft furnace of ensions, will **add** from 8 to 15 h. p. to that of the

nensions of Water Tube Boilers.—In Table No. en the average dimensions of **water tube boilers.**

CHAPTER IX.

QUESTIONS AND ANSWERS ON PREC CHAPTERS.

Q. What is the difference between a plain t a submerged tube vertical boiler?

A. In a plain tube, or dry top boiler as it times called, the **ends** of the tubes are not cove water, while in the submerged tube boiler the the tubes are submerged or kept covered with all times.

Q. Which type of these boilers is preferab

A. The submerged tube type, as the tubes a sheet are less likely to be **burned.**

Q. How are vertical boilers usually set?

A. The smaller types are self contained, w larger boilers rest on a foundation built in the g

Q. Are the Cornish and Lancashire boilers ally or internally fired?

A. They are **internally** fired.

Q. How are vertical boilers fired?

A. They are generally **internally** fired.

Q. How are return tubular boilers fired??

A. They are **externally** fired.

Q. What are the advantages claimed for in fired boilers?

A. That they are more **economical in the** fuels, and also are **self contained.**

Q. What is the chief objection to internal boilers of the Cornish and Lancashire types?

A. The liability of the flues to **collapse,** o the steam pressure being on the outside of the

Q. Why are the tubes in a water tube boiler set at angle, or inclination?

A. To facilitate the circulation.

Q. How much is this inclination?

A. Usually one inch to twelve

Q. Why are water tube boilers claimed to be safer fire tube boilers?

A. On account of the small amount of water con-d in the tubes of same, and also owing to the small eter of the tubes.

Q. Name some of the advantages of water tube ers?

A. They are, (1) safety from explosion; (2) tubes likely to rupture; and (3) their quick steaming ities.

Q. Name some of the advantages of the internal ace boiler?

A. The chief advantage of this type of boiler is the omy of first cost, they being "self contained," there-e the expense of setting is saved.

Q. What is meant by a "self contained" boiler?

A. A boiler that is independent of any masonry ing, cast iron fronts, buck stays, tie rods, and etc., permitting them to be easily removed from one ality to another.

Q. What other advantages do they possess?

A. They are capable of carrying an extremely high pressure, and are at the same time steady steamers. y are extremely economical in the consumption of owing to the absence of all brick settings, which set-usually crack and allow the heat to escape.

Q. What is the principal advantage of the multi-ar boiler?

A. Its cheapness.

Q. What is the most common type of tl motive boiler?

A. The **fire box** boiler.

Q. What are the principal **disadvantages** boiler?

A. The necessity of bracing and staying tensive **flat** surfaces, also imperfect circulation ficulty in keeping water leg clean.

Q. What is a **sectional** boiler?

A. A boiler made up of a number of sec units. These sections are usually of cast iron about 8 inches in diameter and connected by necks. The Harrison boiler is one of the best types of this boiler.

Q. How is **boiler steel** usually made?

A. It is made by the **open hearth** process.

Q. What is the chief ingredient of all com iron and steel?

A. Pure iron, of which they contain from cent to 99 per cent.

Q. What is the principal difference wrought iron and steel?

A. The amount of **carbon** contained in th make steel from pig iron it is necessary to burn bon out of the iron, and to make it from wrough is necessary to add carbon to it.

Q. What is meant by the open hearth proce

A. In this process the gas and air needed f bustion are heated to over 1,000 degrees Fahren fore entering the combustion chamber. To the metal certain chemicals are then added to keep state of agitation, which takes the place of pud stirring it.

Q. What is the Bessemer process?

A. In this process the molten pig iron is pu large pear-shaped vessel called the "Converter," is forced through it under pressure. The air through the molten metal burns out the carbon, etc.

CHAPTER X.

LEADING TYPES OF BOILER AND FURNACE ATTACHMENTS.

Pressure Gauges.—In Fig. 69 is shown a sectional view of the Bourdon Steam Gauge, which is the standard pressure gauge now in use. The principle upon which this gauge is constructed has heretofore been explained.

Pressure Recorder.—In Fig. 93 is shown a pressure recorder. This device, or recorder, can be used on steam, gas, water and all forms of pressure, to corectly record the fluctuations and pressure for a given time. With these instruments, is usually furnished an ample supply of charts, ink, etc., also printed instructions.

By using such pressure recorders, the fluctuations in the steam are correctly recorded in ink upon a chart, which permits the operation of the boiler to be inspected daily. Such recorders are therefore a great assistance to the chief engineer in keeping a careful oversight over the firing of the boilers, and the labor of attendants.

Gauge Frame.—In Fig. 94 is shown a gauge frame for the engine room, which permits the engineer to know at all times exactly what is being done in his plant.

THE LUNKENHEIMER POP SAFETY VALVE.

Construction.—In Fig. 95 is shown a well known type of a Pop or Spring Safety Valve. These valves consist of the iron body A into which is firmly screwed the bronze seat ring E, having a bevel seat at an angle of 45 degrees. The seat ring is provided with the regulating ring F, which can be screwed up or down to regulate the pop and is held in any desired position by means of the regulating ring screw H. The disc D is well

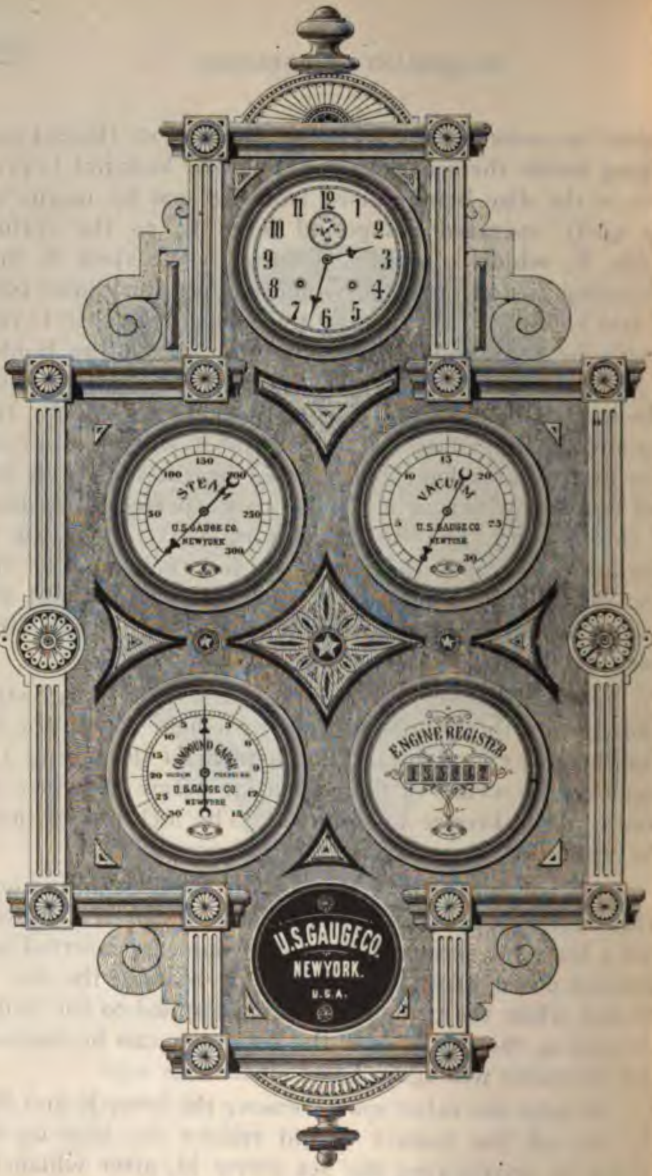
A Pressure Recorder.
Fig. 93

by means of the wings on the bottom thereof op- inside the seat ring E. The disc look-nut G per- the disc being raised from its seat by means of ly operated compound lever K, as the spring R, which is rigidly secured to the stem X, has g wings on same which engage the under part ock-nut. By turning the stem X the disc D can be reground, as the wings on the spring holder e correspondingly shaped recesses in the disc. e steel spring J is firmly held in place by the bottom plates Q and P, and it will be observed e plates have ball shaped bearings at both top om, which at all times insure perfect alignment pring. The casing forming part of the top B ly encases the spring J, and the action of the not be affected by back pressure should the pipe be cramped or muffled, as the top of same within a bronze spring casing ring.

top B is securely held to the body by large steel hile the bonnet C is in turn held to the top by nze cap screws. The tension of the spring J is l by means of the regulating screw M which op- the bronze bushing O. The lock-nut N holds lating screw in any desired position.

not necessary to change the pressure adjustment ting the boiler, as the screw S can be removed, ng set screw of the same diameter inserted and down upon the valve stem, holding the disc to while the pressure is being applied to the boiler. as the test is over the set screw can be removed valve will again be as efficient as ever.

ake the valve apart, remove the lever K and fork off the bonnet C and relieve the load on the y unscrewing the set screw M, after which the



A Gauge Frame for Engine Room.

Fig. 94.

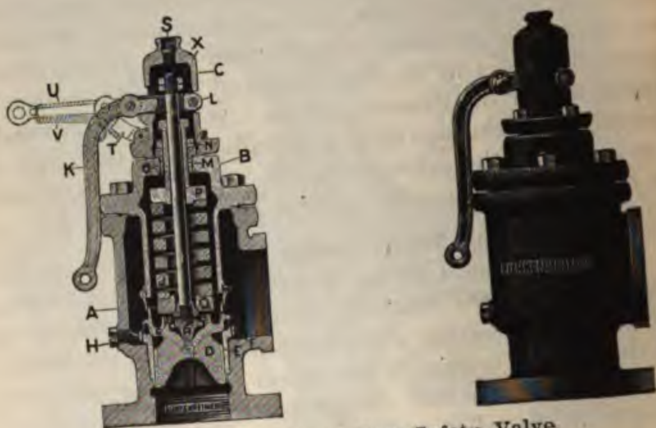
top B can be removed, when access to the interior can readily be had.

To set the valve at a higher pressure, turn the regulating screw M down, and for a lower pressure, turn regulating screw up. The pop or action of the escaping steam is regulated by the ring F, which is easily accessible without taking the valve apart by removing the screw H and inserting a rod to engage the notches around the regulating ring F. If the valve pops suddenly, and does not reduce the pressure enough, turn ring F up, which covers the holes in the seat ring and causes the disc to remain longer off its seat. If the valve pops too much, opening and closing only gradually, turn the ring F down. When the desired adjustment is obtained, secure the ring F by means of the screw H.

Quick Closing Water Gauge.—In Fig. 96 is shown the Huyette Quick Closing Water Gauge. It is impossible to prevent the breaking of water glasses, owing to their sudden expansion when steam is raised in the boiler, and the sudden release of the steam upon their breaking is a source of constant danger to the engineer, and of scalds or burns when trying to shut off the gauge when the glass breaks.

With a quick closing device all that is necessary is to pull the chain which is sufficiently long to always be in easy reach of the attendant, and which closes the gauge valve both at the top and bottom, as seen from the cut, thus preventing further escape of the steam.

Safety Water Column.—In Fig. 97 is shown the Wright Safety Water Column. The chamber shown at the bottom, is for the collection of sediment. The **whistle** is shown on top of the column. When the water varies above or below the proper level, the whistle sounds an



The Lunkenheimer Pop Safety Valve.

Fig. 95.

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The Huyette
Quick Closing Water Glass.
Fig. 96.

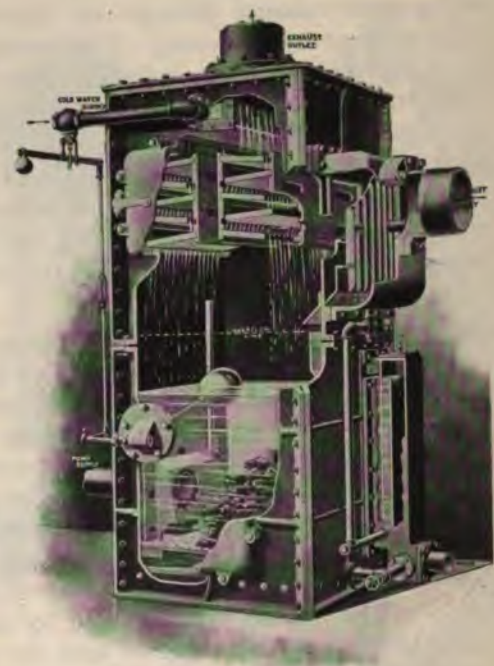
The Wright Safety Wa
Fig. 97.

with passages between the tray supports and the sides of heater, (and between the sets of trays in heaters having two or more sets), giving greater area for the passage of any surplus exhaust through the heater than the area of the exhaust inlet opening. This arrangement provides for delivering steam, by induction, through the opening in the tray guides to the water as it flows from tray to tray.

Introduction of the Water.—From the cold water opening in the heater the cold water is conducted to an open distributing box, or trough, extending across and above the trays. Over the serrated sides of the distributing box the water flows to the upper trays.

Controlling the Water Supply.—Outside of the heater, on the inlet pipe, is placed a balanced valve for regulating the cold water supply, which valve is controlled by a ventilated copper float carried in the heater. Any change in the level of the water raises or lowers this float, opening or closing, by crank and lever connections the regulating valve, thus keeping supplied the demands that are being made upon the heater for hot water, and preventing any waste of water through the overflow. The ventilation of the float is accomplished by using a hollow brass stem connected to a hollow axis, the end of which projects without the heater. A suitable brass stuffing box prevents leakage, the lower portion of the stem of the float being submerged, so that any water that may accumulate in the float from sweating through the copper, or from leakage, will show on the outside of the heater, within plain view of the engineer.

Skimmer, Overflow and Water Seal.—Just above the working level of the water, and extending the width of the heater, is placed a skimmer for taking off impurities that rise to the surface. Back of this skimmer is a



The Cochrane Feed-Water Heater and Purifier.
Fig. 98.

trough or overflow which is drained through an opening in the side of heater into the water seal or trap, which seal, while of ample size and perfectly open, carries a sufficient head of water to withstand a pressure of about one-half pound to the square inch.

Plates for Carrying Filter Bed.—To provide for carrying additional depositing surface in the form of a filter bed, this heater is furnished with perforated cast iron plates or shelving, on which the material used is placed, thereby insuring the passage of all the water through the filtering bed, and providing an easy course to the pump supply via the hood. These plates form a false bottom, being set at least four inches above the bottom of the heater.

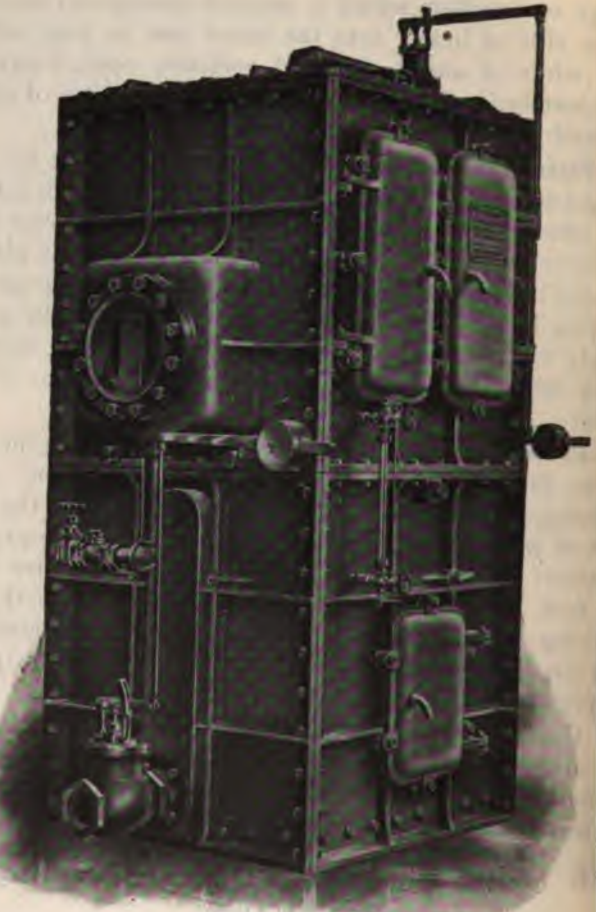
Protection to Pump Supply Pipe.—Covering the outlet to the pump, and extending down to the coke shelving, is a hood, open at its under edge for the passage of water, and vented by a pipe at the top to prevent possible air-logging and consequent interference with the flow to the pump. This pipe also prevents the syphoning of water from the heater, thus maintaining a seal for keeping the floating impurities from the pump supply pipe.

Every provision is made for examining and cleaning all parts of the heater without disturbing any pipe connection, the openings being of large size and conveniently located.

THE WEBSTER FEED-WATER HEATER AND PURIFIER.

Fig. 99.

Construction.—The Webster "Star-Vacuum" Feed-Water Heater, Purifier, Filter and Receiver, consists of



The Webster Exhaust Steam Feed Water Heater and Purifi

Fig. 99.

a cast iron receptacle in which cold water and exhaust steam are brought into direct contact.

The illustration shows clearly the construction and operation of a very well known style, built for boiler capacities of from 500 to 5,000 horse power. It is of the standard Webster type—an exhaust steam feed-water heater, in combination with a filter and precipitating chamber.

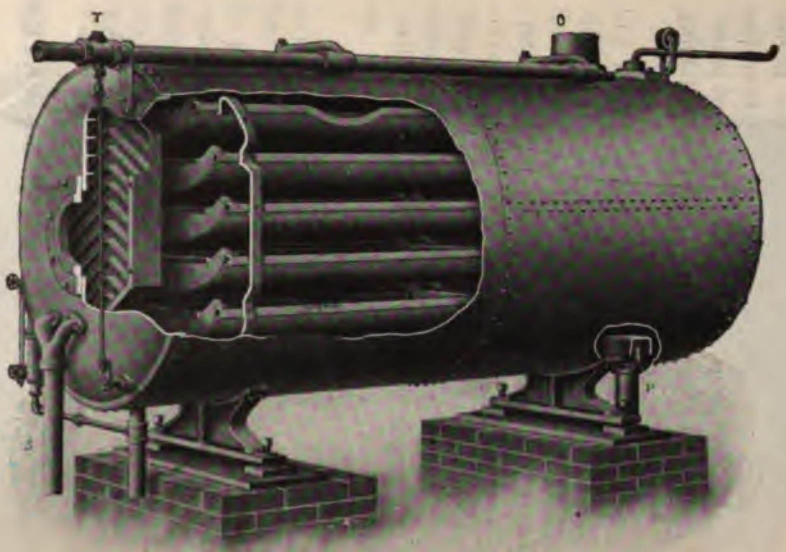
The heater is further provided with a Webster Oil Separator, which is made a part of the heater construction, which effectually and completely removes the oil present in the exhaust steam before it enters the heater; also with automatically regulated water supply and overflow; quick-opening drain valve or blow-off; sealed outlet for the heated and purified water fed to the boiler feed-pumps; charging and cleaning doors for the filter; removable tray doors; combination vent and inlet air valve; gauge glass, and other fixtures.

The materials used in its construction are cast iron for the shell, and copper and brass for the valves and fixtures; each of which resist the destructive action of impure waters. The large heating chamber—upper section of the heater—is provided with perforated copper trays for the distribution of water as hereinafter explained. The entire valve gear, automatically controlling the water supply and overflow, is of brass.

THE HOPPES EXHAUST STEAM FEED-WATER HEATER.

Fig. 100.

Description.—The shell is of steel plate, and heads are of cast iron, the front one being removable for taking out the pans for inspection or cleaning.



The Hoppes Exhaust Steam Feed Water Heater.
Fig. 100.

The exhaust steam enters at the back end, and after passing through the large oil eliminator, the purified steam enters the heater proper, from which it escapes through the pipe O at front end.

The water, on entering the heater at T, is fed into the top pan and, overflowing the edges, follows the **underside** of the pan to near center, when it drops into the next pan below. It flows over each successive pan in the same manner until it reaches the chamber at the bottom, from which it passes to the pump through pipe P.

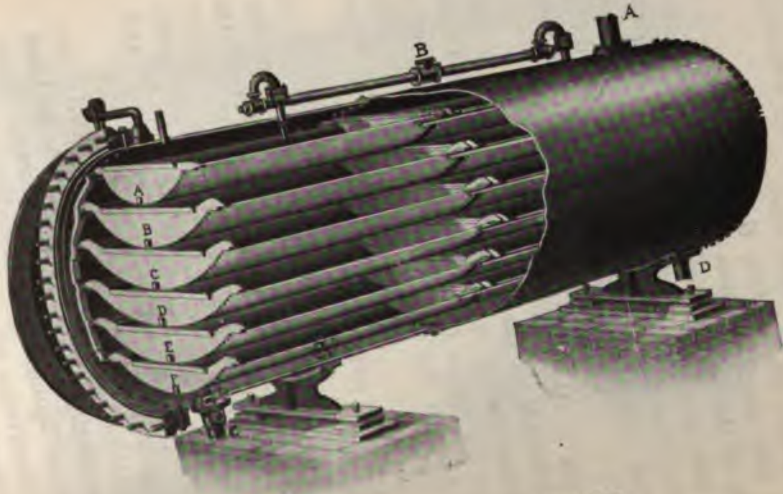
While the heater is in operation the water flowing along the **underside of the pans comes in direct contact with the exhaust steam** passing through the heater, and in this manner the water is heated without the heat having to pass through the pans or lime already formed thereon.

The **inside** of the pans afford settling chambers for the mud and solids in suspension, while the lime and other solids in solution form on the **underside of the pans.** The water is thus not only heated to the highest degree obtainable by exhaust steam, but all of the solids that are separated at that temperature are caught and retained in the heater.

Setting and Connection.—The heater should be set in a position that will bring the bottom of same **at least two feet above the suction-valves of the pump.** After the heater is placed on foundation it should be **leveled both ways** by the set-screws at corners, a spirit-level being placed on the leveling bar on top of heater.

The exhaust inlet should be connected at back end, and the outlet at the top. Connect the suction at P. B is blow-off or drain.

The water column may be placed on either side,



The Hoppes Live Steam Purifier.
Fig. 101.

ing provided in each side of heater for top con- one of which is plugged. The overflow and on small heaters are connected with a Y, and ıld be connected to sewer. Where the heater in a heating system, a trap should be used in .

.ttaching the float and valve, first secure the in place, with arrow on side of valve pointing the heater.

ove the head, take out the pans, and get inside , and put the float in position by running the m through the stuffing-box from the inside, re- small iron lever on the outside end, drive in and connect the lever with the valve-stem by ıown in cut.

length of the rod can be adjusted to give any ıeight of water in the heater. Carry the water ı enough not to run out of the overflow. A e should be placed on the feed-pipe to shut off r, as the regulating valve is intended for regu- ly.

E HOPPES LIVE STEAM PURIFIER.

Fig. 101.

struction.—The purifier consists of a round best flange steel, having a solid, pressed flange d riveted in the back end, and a solid pressed eel head bolted to a heavy ring to the front end

pieces being malleable iron, whereby a very light, strong and durable construction is obtained and a degree of elasticity or resilience secured to the pans, which permits the lime or other incrustations being easily removed. The ends of the pans are higher than the sides, and have projections at each extremity to rest on the ways on which the pans are adapted to slide.

The ways on which the top pans slide are curved downward opposite the feed inlets, to permit the heads of the pans to pass under the ends of the feed pipes.

The sectional cut illustrates a purifier with two tiers of pans and six pans in each tier, and the arrangements for dividing and distributing the feed-water in the top pan of each tier.

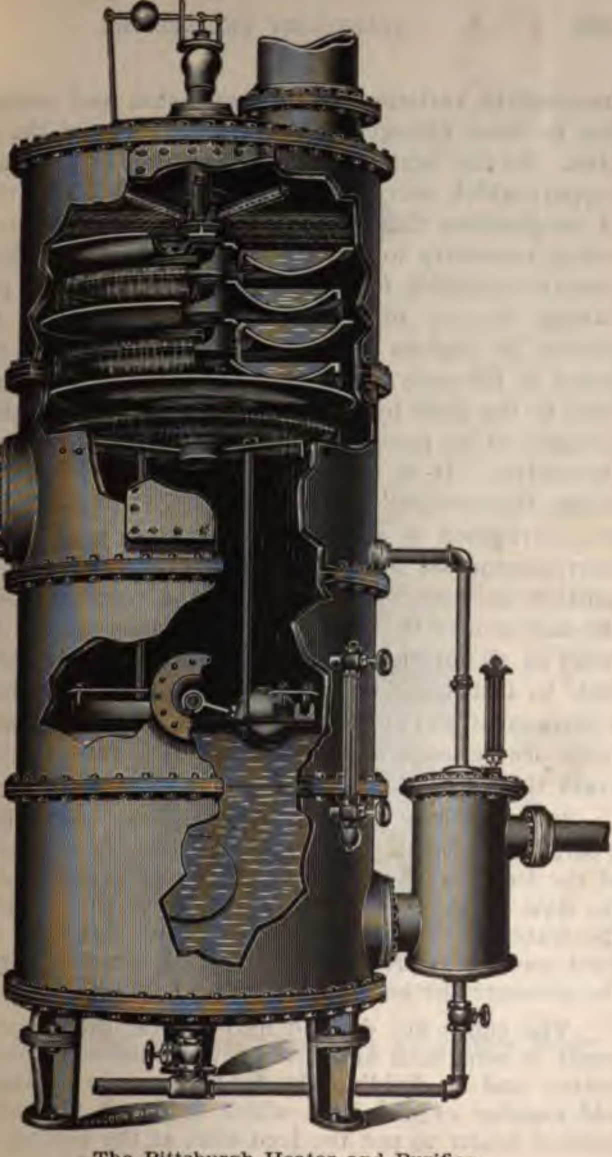
The purifier is connected to the boiler by a large steam pipe A and the exit or gravity pipe D. A blow-off pipe is also connected to the purifier at C.

The feed pipe from the pump or boiler feeder is attached at B.

A water column and gauge is also connected, as shown in the exterior view of purifier, and while in operation this gauge should never show more than half full of water.

In packing the head, round asbestos packing is placed in a groove turned in the ring, and is held in place by the head. This makes a most effectual and lasting joint, and dispenses with the use of large gaskets.

Setting and Connecting Purifier.—The purifier should set above the boilers, or in a position that will bring the bottom of shell two feet or more above the water-level of the boilers. After it is in position, the purifier should be leveled both ways by means of the set-screws at each corner. The main steam pipe A should be connected to an independent steam header,



The Pittsburgh Heater and Purifier.

Fig. 102.

commodate variation in the expansion and contra
due to these changes upon various parts of the a
atus. As the heat-transferring medium is preferab
copper, which moves to a greater extent under cha
of temperature than the containing shell of iron, i
comes necessary to provide means to accommodate
almost-irresistible force in such a manner as to pre
damage to any of the parts. This has been ac
plished in various ways: by screw glands or stu
boxes at the ends of each tube; by connecting one
head to the shell by means of a flexible or movable
phragm, or by providing for this expansion in the t
themselves. It is this latter method that is empl
in the Wainwright Evenflow Heater, the tubes of w
are corrugated in such a manner as to take up in
convolutions the movement due to the difference o
pansion or contraction between the copper tubes
the cast iron of the shell. Having thus provided fo
relief of all interior stresses or strains, it becomes
sible to fasten rigidly the tubes into the tube head
a permanent and substantial manner. In this heate
tubes are fastened at each end into the tube plates
brass thimble.

This method is extremely simple and effe
There is but a slight and entirely negligible redu
of the free area and no irregular projections to obs
the flow of water. As a matter of fact the tenden
the water pressure is to increase the tightness o
joint and consequently, within wide limits, the gr
the pressure the more secure the fastening.

The tubes are divided into several groups and
water is sent back and forth several times throug
heater, and in dividing the tubes there is arrange
odd number of divisions, which makes it possible
vertical heater to put the feed inlet at the bottom o

Wainwright Vertical Water Tube Feed-Water Heater
Fig. 103.

heater and the outlet at the top. This arrangement also allows the exhaust openings to be placed so that the cold entering water meets the outgoing steam, while the heated water, just as it leaves the heater, receives the full benefit of the entering exhaust.

Although the velocity of flow is much greater than in ordinary heaters, it does not even approach a velocity which produces friction enough to offer any objectionable feature. This point has received very careful consideration, and a velocity high enough to produce enormous heat transmission is secured with less friction than is encountered in the feed pipe itself.

THE BUNDY STEAM AND OIL SEPARATOR.

Fig. 104.

Construction.—Consists of a cast iron flanged body and a catch basin or receiver flanged to the body at the bottom. A nest of baffle or separating plates are placed in the body at right angles to the direction of steam travel. These plates are set staggered. They consist of upright columns with interior channels and cup-like openings to catch the water of condensation. The steam describes a zig-zag or winding course as it passes through this nest of plates from the intake side of the separator to the outlet side.

Operation.—When used as oil separators to extract oil from exhaust steam, the separator is placed as close to the engine as conditions will permit, the intake side being the face or front of the separating plates. As the steam passes through the nest of plates, the oil which it contains, and which is held in suspension, becomes entangled with the plates, is collected by the small cups, and passes down through the channels, dropping into the catch basin or receiver. A tapping in the

...nal View of the Bundy Steam and Oil Separator.
Fig. 104.

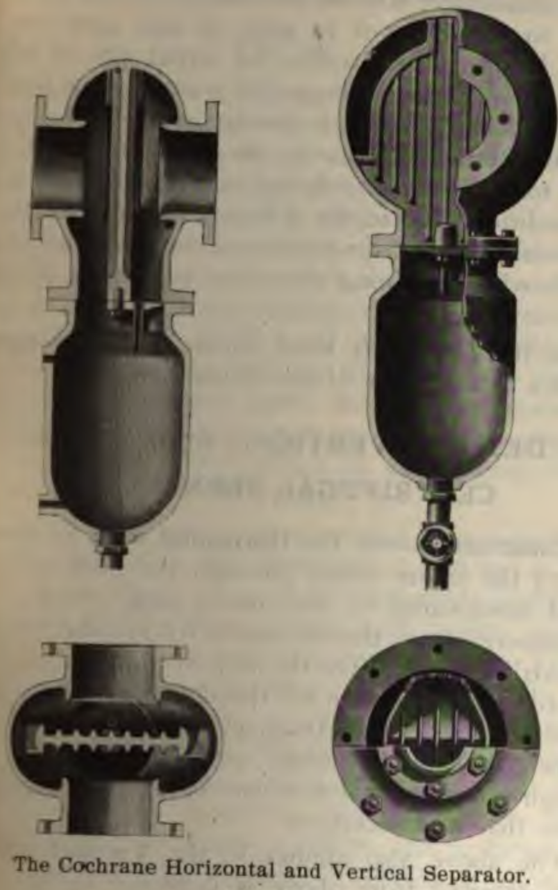
bottom of the receiver permits the connecting up of waste pipe through which the oil passes off, either gravity or through a suitable steam trap. This sep ator is designed to have the side cover plate removab by taking off the bolt heads, swinging it to one sid thus permitting the interior separating plates to be tak out by hand for the purpose of cleaning. It is recor mended that these plates should be cleaned about on each fortnight, immediately following the installatic of the separator, and at intervals as may be required other times. Where necessary, separators will be pr vided with the removable cover plate flanged to the t of the body. In some plants there is not sufficient roc to take the plates out from the side, in which event th should be removed from the top.

THE COCHRANE SEPARATOR.

Horizontal and Vertical Forms.

Fig. 106.

Construction.—A single baffle plate facing the in opening, presenting sufficient surface for the impin ment of all the particles of liquid traveling in the c rent—ribbed vertically to prevent the side travel of separated liquid—ports are placed one on each side the baffle, and these combined, of an area exceeding t of the entering pipe—the opening into well being f and placed directly in front of and underneath the of the entering pipe, so that when a large quantity of uid comes it will pour directly into the well. The w being entirely below the course of the current, and current not being discharged into it, the liquid tal out will not be disturbed until it rises to the level the bottom of the main, when the Separator simply



The Cochrane Horizontal and Vertical Separator.

Fig. 106.

comes inoperative without the current having the opportunity to drive out or to pick up and carry over the stored liquid. The chamber on **outlet side of baffle** i closed to well, the drainage for condensation from this chamber being led to well through an internal drip pipe.

The Vertical Form.—Is the equivalent of the horizontal form, modified in design and construction to meet the conditions due to the different direction of the current—viz.: upward or downward flow instead of horizontal—while retaining the same principles of separation.

In the lower left hand corner of above figure is shown a section view of this Separator.

THE DETROIT VERTICAL AND HORIZONTAL CENTRIFUGAL SEPARATORS.

Construction.—In the **Horizontal style** as shown in Fig. 73 the steam enters through the inlet and is deflected downwards by the curved arm, and water and any impurities are thrown partly by gravity and partly by centrifugal force into the well of the separator. The purified steam is drawn off through the outlet from the top of the separator. Drainage is accomplished either by means of an automatic steam trap, or by hand through the outlet valve whenever the water gauge indicates that it is necessary.

The above also applies to the **Vertical style,** the steam entering from above is deflected by the curved partition shown in the sectional cut. This partition has a trough on the lower edge to catch any water that may collect on and run down the sides of the partition. The Vertical Separator is not intended to be operated with an **ascending** current of steam.

THE ALBANY RETURN STEAM TRAP.

Fig. 107.

Construction.—It consists of a vessel approximately cylindrical in form provided with a closed bottom. A removable bonnet forms a closure for the upper end of the casing and is secured to the same by screw bolts. An open top copper bucket is enclosed in and arranged to tilt within the casing. The bucket is attached to the casing by a hinged joint in such a manner that it will be free to acquire tilting movements when occasion requires. Channeled guides are arranged within the bucket so as to be practically at right angles to the center line of the hinged joint, and in the guides are spherical counterweights, fitted to roll to complete the tilting movement of the bucket by gravitating toward the depressed ends of the guides.

A valve-operating rod is connected by a joint to the bottom of the bucket; the upper end of said rod is fitted to move more loosely in a chambered guide secured to the bonnet. This rod is provided with tappets projecting latterally therefrom and are adapted to take against the inner end of the equalizing valve lever. The tappets are spaced sufficiently apart to afford a degree of lost motion between them and the corresponding end of the equalizing valve lever. The equalizing valve is for the purpose of, on occasions, admitting steam direct from the boiler into the trap cylinder, and is shown connected to the removable bonnet. This same equalizing valve casing contains the small exhaust valve that is useful in some cases, as will be hereinafter explained.

The inlet check valve is the one through which the water of condensation is conveyed into the steam trap, by which communication between the steam trap and

The Albany Return Steam Trap.

Fig. 107.

the system of heating pipes will be controlled at proper times and in a proper manner.

The outlet or discharge pipe will be connected from the steam trap with the water space of the steam boiler, and to prevent a back-flow of water from the boiler into the trap the check valve is placed in the discharge pipe below the water line in the steam boiler. It will be noticed that the discharge pipe extends downwardly into the bucket and reaches nearly to the bottom of the same, so that when the steam pressure is admitted into the steam trap the water contained in said bucket will be forced to flow upwardly through said syphon pipe and thence through the outside discharge pipe and check valve into the boiler.

The air cock on the top of the discharge chamber is to relieve the discharge pipe of any air in first starting the trap in operation. The automatic air valve is adjusted to relieve any accumulation of air from the trap cylinder during its regular operation.

Operation of the Trap in Connection with a Heating System.—In a general way the operation of the trap in connection with a heating system will be: The water of condensation being forced from the coils (or heating surface) through the inlet check valve and opening H (see vertical section, Fig. 2) into the space G between the bucket and outer case, the bucket F will begin to move upwards, caused by the floating power of the water contained between the bucket and the casing when said bucket is tilted sufficiently. The ball weights C will roll on the channeled guides A to the side of the bucket that is adjacent to the hinge joint, thereby providing a sudden impulse in the tilting movement.

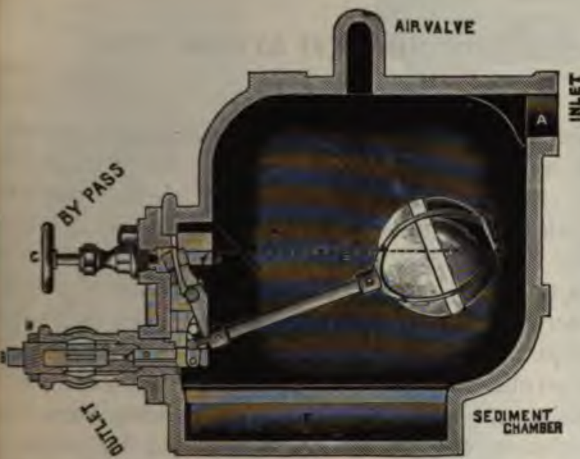
The tilting movement just referred to will, through the action of the valve lever I bring the inlet equalizing

steam valve J on its seat, at the same time through the action of the valve lever it will lift the exhaust valve K from its seat.

The water will continue to flow through the opening H into the space G, and when the space is filled it will flow over the upper edge of the bucket. When the bucket has become nearly filled with water the preponderance of weight causes the bucket to tilt downward, causing the ball weights to roll on the guides to the opposite side of the bucket, thereby providing a sudden impulse downward, and in making such downward movement the upper tappet E on the valve rod B will touch against the inner end of the valve lever I and suddenly open the inlet equalizing steam valve J for the admission of boiler steam. After the pressures have been equalized between the trap and the boiler, the water will begin to gravitate out of the bucket through the syphon pipe D, passing through the pipe D and discharge check valve into the boiler. After the water has been nearly all discharged from the bucket, the water between the bucket and outer case will cause the bucket to move upwards. When said bucket is tilted sufficiently, the ball weights C will again roll to the side of the bucket adjacent to the hinge joint, and as before explained suddenly close the inlet steam valve. After a few seconds, from condensation (or the escape of steam through the exhaust opening M) the pressure in the trap case will become enough reduced so that the condensed water from the system will again enter the space G and will continue repeating the operations as before described.

THE ANDERSON STEAM TRAP.

Construction.—In Fig. 108 is shown a sectional view of this trap, from which can be seen its general construc-



The Anderson Improved Steam Trap.
Fig. 108.

Sizes, Capacity, Etc.

Number of Trap	1	2	3	4	5	6	7
of Pipe connections, in inches	½	¾	1	1¼	1½	2	2½
discharge of condensation per hour in pounds	750	1,200	2,000	2,900	4,000	6,000	12,000
number of square feet of surface that should be applied	500	800	1,300	2,350	3,500	5 000	10,000
number of lineal feet of 1 in. pipe surface that should be applied	1,500	2,500	4,000	7,000	10,000	15,000	30,000
Weight, in pounds (boxed)	54	67	93	112	145	190	440

tion, while below the cut is given its general sizes and dimensions.

THE BRANCH STEAM TRAP.

Fig. 109.

Construction.—The illustrations represent the exterior and interior respectively of the Branch Steam Trap. By referring to the sectional view it will be seen that while the construction of the trap is exceedingly simple, its action is based on a system of double levers which is entirely new. This trap consists of a cast iron cylinder with a heavy flange at the upper end to which is bolted the cap of the trap. This cap is so constructed as to permit either a vertical inlet for the steam, or horizontal, as may be desired. The working parts consist of a system of double levers operated by means of a copper float, through which passes loosely a rod having a valve at its lower end and a nut at its upper end which is acted upon by the levers. The extreme sensitiveness and effectiveness of this trap is apparent from the following example: Assuming the weight of the float, to be 9 pounds, normal line of flotation 6 inches above the bottom of the float, diameter of valve 11/16-inch or 37.12 area in square inches and the boiler pressure 100 pounds, then the pressure on this valve is equal to 37.12 pounds. Ratio of lower lever is 2.5:1. Ratio of upper lever is 2:1. Therefore 1 pound pressure against the underside of the free end of the lower lever, is equivalent to 5 pounds pressure of the upper lever against the underside of the lifting end of the valve stem.

That is to say, when the float is pressing against the lower lever with a force of say 7.60 pounds, the lifting force of the upper lever on the valve spindle will be 7.60x5 or 38 pounds, which is sufficient to raise the

The Branch Steam Trap.
Fig. 109.

Sizes and Capacities.

	No. 1.	No. 2.	No. 3.	No. 4.
all, inches............	38	27	18	12
connection............	1½	1¼	1	½
side, inches...........	10	8	6	4
tside, inches..........	11¾	9½	7¼	5
nge, inches............	15	12	10	7¼
nd sides, inches.......	1½	1¼	1¼	1
, inches...............	1⅛	1	⅞	⅝
m, inches..............	1⅛	1	¾	⅝
nds....................	300	130	90	30
l inch pipe that drain................	27,000	13,500	6,000	2,300
quare feet of	8,500	4,800	2,000	850
bs of water per hour..	3,000	1,800	275	225

valve, and allow discharge of condensation. The lev of the condensation when the float is about to lift t valve, is 11 inches above the bottom of the float, whic insures the trap to carry at all times plenty of wate The valve will close instantly when the water dro slightly below its level when lifting the valve, there causing the float to drop out of contact with the low lever. The efficient manner in which this trap w handle large sudden floods of water is at once appare

It will therefore be seen that by the employment the Branch System of double levers, that the lifti force or efficiency of the float is increased **five time** thus making this the most **sensitive** steam trap on t market. The valve is provided with a removable se which can be replaced at any time from the outsid The trap is designed to work successfully under pressures from 1 to 250 pounds, and to deliver wat against any back pressure not exceeding 3 pounds le than the pressure of steam in the trap. All traps a furnished with a glass water gauge, blow-off cocks, a are tapped suitable for any size of pipe.

THE BUNDY RETURN STEAM TRAP.

Fig. 110.

Construction.—This return steam trap is govern in operation by the dead weight of the water. R ferring to Fig. 110, the machine consists of a cast i receiving bowl elongated to form a neck, the wh mounted on a frame of cast iron, with a steam valve a an air valve underneath the steam valve, and a h zontal lever, with a balance weight, resting on the r and extending horizontally over the receiving bo Water will flow into the receiving bowl until the weig of the bowl and water combined is sufficient to ov

The Bundy Return Steam Trap.
Fig. 110.

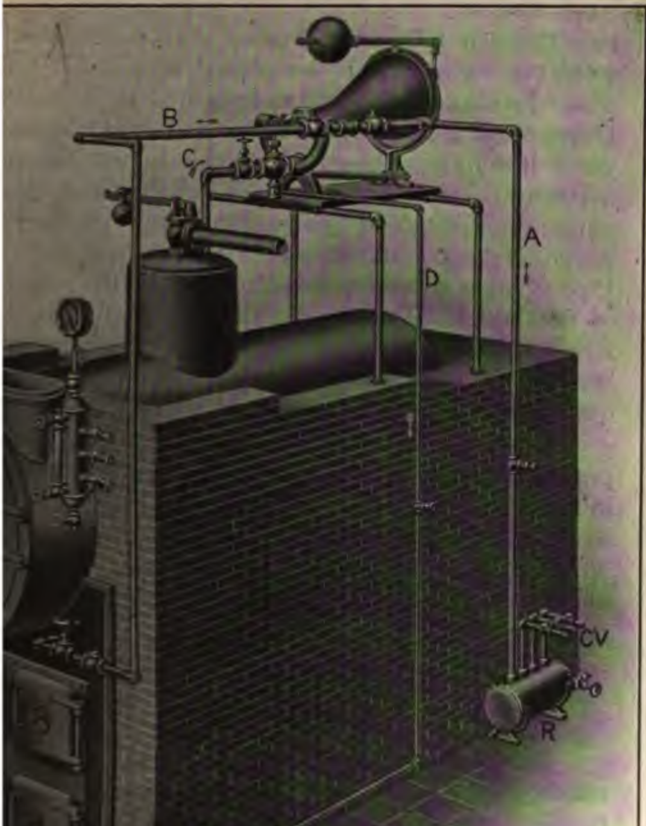
The Bundy Tank Steam Trap.
Fig. 112.

come the weight of the counter-balance and caus bowl to drop down to the bottom of the ring. see-saw motion imparted to the valve stem of the s valve on the front of the trap, through a ring or r extension piece which is screwed into the neck of receiving bowl, and swung on lateral trunnions, steam valve is opened, admitting live steam from boiler and permitting the contents of the receiving to pass into the boiler by gravity. The trap its placed 3 feet higher than the water line of the b and, by equalizing the pressure on the trap with pressure on the boiler, and with 3 feet head, the w must leave the trap and go into the boiler. The c valves shown are placed respectively, one in the in pipe and the other in the discharge pipe. When er the counter-balance weight pulls the receiving back to its original position and opens the air va permitting the trap to vent itself of steam and air.

THE BUNDY RETURN STEAM TRAP PLAC OVER BOILER.

Fig. 111.

Construction.—From this cut can be seen how open steam trap, placed over the boiler 3 feet above water line, can be made to operate successfully. W of condensation from coils or heating apparatus steam using machines gathers in receiver R, each in pipe being fitted with check valves, C V. Condensa passes through pipe A and enters the receiving bow the trap through the intake check valve. At discha live steam from the boiler enters the trap through C, the water passing from the trap into the bo through pipe B. When empty, the exhaust from trap passes through pipe D and is usually dischar



he Bundy Return Trap Placed Above Boiler.
Fig. 111.

into the ash pit of the boiler. An extra check valve and stop valve should be placed in pipe B below the water level of the boiler, as indicated in Fig. 111. Pipe D must be connected into the boiler as far below the water line as possible, preferably into the blow-off of a horizontal tubular boiler. No other feed pipe from pump, or injector, or apparatus of any description, is allowed to be connected into the boiler through pipe B. Pipe C must communicate directly with the steam space of the boiler. There must be enough pressure of live steam or head of water to lift the condensation from receiver R into the trap. One pound pressure is required for each 2 foot elevation.

These return traps are frequently used as "lifting pumps" to elevate water or other liquids from one level to a higher one; also to extract condensation from exhaust pipes of condensing engines subject to vacuum; in other cases as **water meters** to measure and weigh the quantity of water discharged from steam using apparatus within a given time.

THE BUNDY TANK STEAM TRAP.

Fig. 112.

Construction.—This trap is designed to discharge condensation into the atmosphere, into open or closed receiver, but never directly into the steam boiler. Its operation is governed by the dead weight of the water in precisely the same manner as the return trap. While the trap is discharging, however, the water passes out of the trap through the steam valve, which valve is closed tightly by the return motion of the receiving bowl. Place the trap below the heating coils or steam using apparatus from which it is to receive condensation. Connect the intake pipe into the opening pro-

ugh the right hand trunnion, through an interior in the right hand horn of the yoke, and through m valve. For each pound pressure carried, the ll elevate the water about 2 feet.

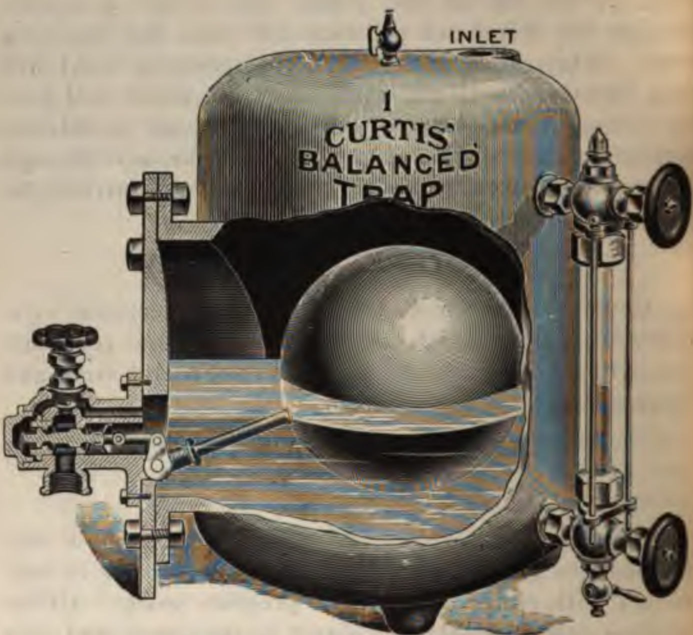
THE CURTIS BALANCED TRAP.

nstruction.—In Fig. 113 is shown a sectional view trap, from which can be seen its general construc- hile below the cut is given its general sizes and ions.

THE DAVIS STEAM TRAP.

Fig. 114.

nstruction.—This trap is a continuous flow trap d for general service and suitable for use in con- with either high or low pressure work. All the g parts are attached direct to the cover, and may noved without disconnecting the pipes. The which control the discharge of the condensation, lanced at every point of their throw and are so cted that the inevitable dirt, grit and sediment enter the trap will not interfere with its opera-



The Curtis Balanced Steam Trap.

Fig. 113.

Sizes and Capacities.

No.	000.	1,000 feet	½	inch inlet and outlet.
No.	00.	1,500 feet	½	inch inlet and outlet.
No.	0.	2,500 feet	½	inch inlet and outlet.
No.	1.	4,000 feet	¾	inch inlet and outlet.
No.	2.	7,000 feet	1	inch inlet and outlet.
No.	2½.	10,000 feet	1¼	inch inlet and outlet.
No.	3.	15,000 feet	1½	inch inlet and outlet.
No.	4.	26,000 feet	2	inch inlet and outlet.
No.	5.	45,000 feet	3	inch inlet and outlet.

THE KIELY STEAM TRAP.

Construction.—In Fig. 115 is shown a sectional view his trap from which can be seen its general construc-, while below the cut is given its general sizes and ensions.

THE MARCK STEAM TRAP.

Fig. 116.

Construction.—This trap as can be seen by the il-ration, has but one movable part, which consists of ollow tube bent in a crescent shape, the tube being posed of a selected metal, and capable of standing enormous pressure. This tube is filled with a liquid, ch, at 212 degrees Fahrenheit, instantly becomes . The expansive force of this gas is so great, that ends to straighten the tube which causes the valve attached thereto to press against the valve seat, eby closing the trap. The moment the temperature this tube is less than 212 degrees Fahrenheit, the gas ain becomes a liquid, the tube immediately assumes original position, drawing the valve stem away from valve seat and opening the trap, and the trap will ain open until the tube is again heated to 212 de-es Fahrenheit or over.

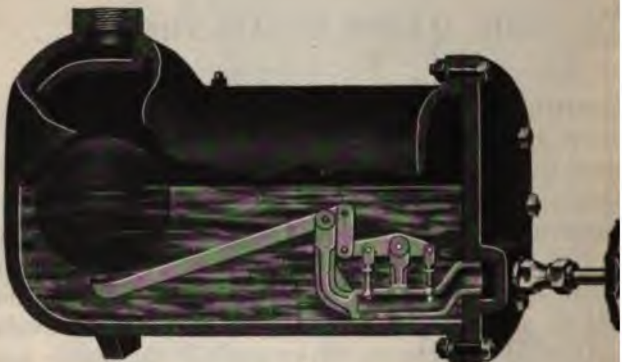
THE McDANIEL STEAM TRAP.

Construction.—In Fig. 117 is shown a sectional view this trap, from which can be seen its general construc-n, while below the cut is given its general sizes and ensions.

THE NASON STEAM TRAP.

Fig. 118.

Construction.—A cast iron reservoir or pot B ed with a cover G provided with two cored passages



The Davis Steam Trap.

Fig. 114.

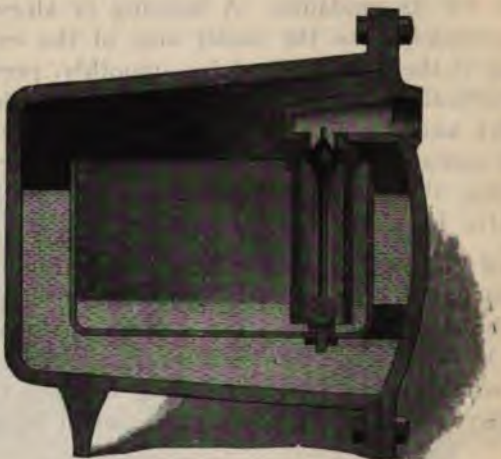
Sizes and Capacities.

Number	00	0	1	2	3
Inlet and outlet ins	½	¾	1	1¼	1½
Capacity, lineal feet of 1-inch pipe	1,500	3,000	6,500	15,000	20,000
Weight, lbs	25	40	60	80	125

contains an open float D which is fitted with a ribbed spindle H for its guidance. A housing or sleeve F is screwed centrally into the under side of the cover G, and within it the spindle H slides smoothly, permitting a short vertical motion. The top of the spindle H is ground flat and its upward movement is arrested by coming in contact with the bronze plug E, having a central opening, the two surfaces thus constituting a discharge valve for these traps.

One of the cored passages in the cover alluded to is for the discharge of water from the trap after passing through the valve E, and the other serves as a by-pass, to permit any large volume of air or water to be blown through, when starting, without going through the discharge valve. Valve K gives entire control of this action.

Operation.—The trap being so placed that the water of condensation flows into it by gravity, the discharge enters at the point marked "inlet" and passing through the cored openings AA into the body of the trap B, a diaphragm C above the float D diverts the water of condensation into the pot or body of the trap B, where, gradually rising, it raises the float D, thereby closing the discharge valve E. Valve K being closed, discharge from the trap is shut off and remains so until the float D becomes nearly filled from the overflow of water into it, when its weight becomes such that it overcomes the tendency of the discharge valve E to remain closed, being held there by steam pressure, and it drops to the bottom, thereby opening the discharge valve E. Acting on the surface of the water, the steam pressure immediately drives it up through the sleeve F (as indicated by arrows), through the discharge valve E, and thence by way of the cored passage to the "outlet."



The Kieley Steam Trap.

Fig. 115.

Sizes and Capacities.

Size Nos.	Size Inlet and Outlet Connections	Capacity Lineal Ft. 1-in. Pipe	Capacity Sq Feet Radiation	Capacit lbs. Wa Per Ho
1	⅜	4,000	1,300	500
2	1	6,000	2,000	725
3	1¼	10,000	3,300	1,200
4	1½	15,000	5,000	2,000
5	2	25,000	8,300	3,000
6	3	35,000	11,500	4,000
7	3	50,000	16,500	6,000

When the float D has been nearly emptied it becomes so light that it is again raised by the water surrounding it, thus closing the discharge valve E, and the operation is repeated. The weight of the float D is such that a permanent water seal always remains over the point of discharge into the sleeve F, thus preventing escape of live steam when the discharge valve E is open.

From the above description it will be observed that the valve action is purposely intermittment, which necessitates that it shall be either wide open or completely closed. The life of the valve is thus definitely prolonged and danger of leakage at this point reduced to a minimum.

THE RELIANCE STEAM TRAP.

Construction.—In Fig. 119 is shown a sectional view of this trap from which can be seen its general construction, while below the cut is given its general sizes and dimensions.

THE WRIGHT "EMERGENCY" STEAM TRAP.

Fig. 120.

Valves at Top.—Three steam-tight outlet valves are employed instead of one. These valves are placed at the **highest point of the trap,** where they are entirely removed from the inevitable grit, scale and sediment, and therefore will not become inoperative from these causes.

In Emergencies.—The action of this trap in emergencies is instantaneous, a feature which renders it invaluable for many uses. The discharge from each of the valves being continuous, is very great—much greater than is possible with an intermittent trap.

The Marck Steam Trap.
Fig. 116.

The McDaniel Improved Steam Trap.
Fig. 117.

Sizes and Capacities—Regular and Low-Pressure Traps.

Trap Numbers	Size of Inlet and Outlet Standard Pipe Size	Drainage Linear Feet of 1-inch Pipe	Equival in Sq Ft of Heati Surfa
12	½ inch	500	166
13	¾ inch	1,500	500
14	1 inch	4,000	1,333
15	1¼ inch	8,000	2,666
16	1½ inch	15,000	5,000
17	2 inch	20,000	6,6
18	2½ inch	25,000	8,33

thus filled, the float rises and opens the center (indicated as valve No. 1 in the enlarged view of arrangement, shown on page 378.)

Valve No. 1 is opened slightly, if there is but little coming in, but widely in event of a sudden in- This one valve is equal to the task of taking care e flow under ordinary conditions, but if the water s into the trap faster than one valve can discharge he water rises in the trap, carrying the float with d opening valve No. 2 sufficiently to discharge the lus water, or wide open if necessary. Valve No. opened in the same manner, providing for the **full city of the inlet pipe,** but it rarely happens that the me of condensation coming into the trap is suffi- t to tax the combined capacity of all three valves. inarily, one valve alone is able to do all the work, ing two valves in reserve for emergencies.

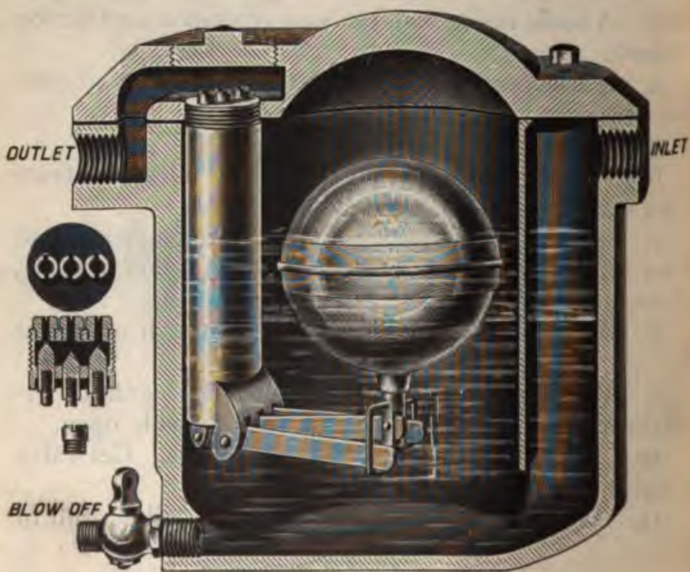
THE HANCOCK INSPIRATOR.

Construction.—In Fig. 121 is shown a sectional view his inspirator, from which it can be seen that its con- ction is very similar to that of the ordinary injector.

The Reliance Steam Trap.
Fig. 119.

Sizes and Capacities.

Size	1	2	3	4	5	6
Size of Connection	½ in.	¾ in.	1 in.	1¼ in.	1½ in.	2 in.
Discharge per min	4 lbs.	7 lbs.	10 lbs.	25 lbs.	40 lbs.	60 lbs.
Feet of one inch pipe Trap will drain	1,000	3,000	4,500	7,500	11,000	16,000



The Wright Emergency Steam Trap.
Fig. 120.

12. Connecting to steam pipe used for other purposes and used at same time.

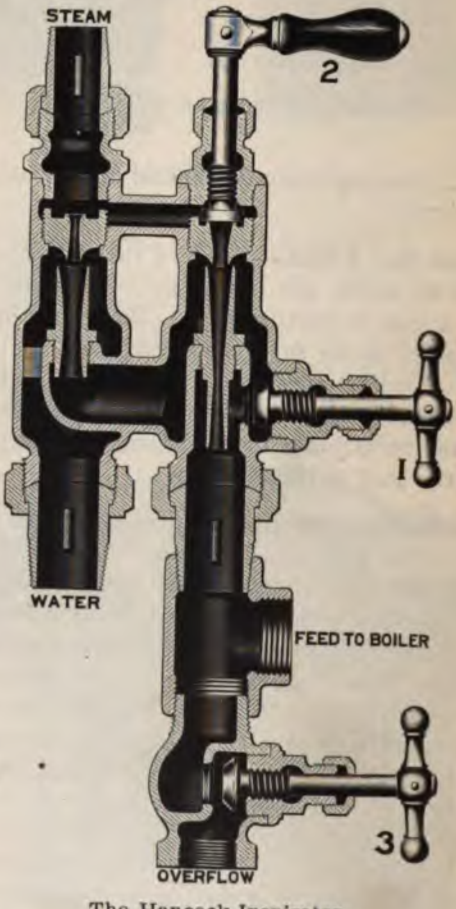
13. Water supply too hot.

14. Not reading instruction card before connecting injector.

15. Overtaxing injector beyond claims made by the manufacturers.

To Test For Leaks.—When a new "Penberthy" injector fails to work, one of the most frequent causes of trouble is a leak in suction pipe. To ascertain if this is the case, fasten down the overflow valve "P," by placing a piece of wood or cork under the cap "." If possible close the lower end of suction pipe and then turn on steam, which will blow back through suction pipe and appear at the leak if there be one.

Where an Injector Lifts Water But Will not Force to Boiler.—This may be due to a leak in water supply pipe, but is more often caused by some obstruction between the injector and the boiler. It often happens that the end of the feed pipe becomes choked up with lime sediment; we have seen a ¾-inch pipe reduced in this way to ¼-inch. Sometimes the injector is compelled to force through a heater that is old and contains many coils of pipe partially clogged up. If you can, place a steam gauge in feed pipe near injector; if it indicates several pounds over boiler pressure when it breaks, it shows an obstruction. At 50 to 100 pounds pressure the "Penberthy" will force against a pressure of 75 to 135 pounds, showing 25 to 35 pounds over pressure, hence it will force at least a part of the water to the boiler until the obstruction is sufficient to create a back pressure equal to this.



The Hancock Inspirator.

Fig. 121.

THE METROPOLITAN AUTOMATIC INJECTOR.

Fig. 81.

Parts.—

S—Steam Jet.

V—Suction Jet.

C-D-R—Combining and Delivery Tube and Auxiliary Check.

P—Overflow Valve.

O—Steam Plug.

M—Steam Valve and Stem.

N—Packing Nut.

K—Steam Valve Handle.

A—Coupling Nut.

B—Tail Pipe.

X—Overflow Cap.

E—Nut for Stem M.

Construction.—By unscrewing the steam plug O, the steam jet S is removed. The suction jet V is screwed into the injector.

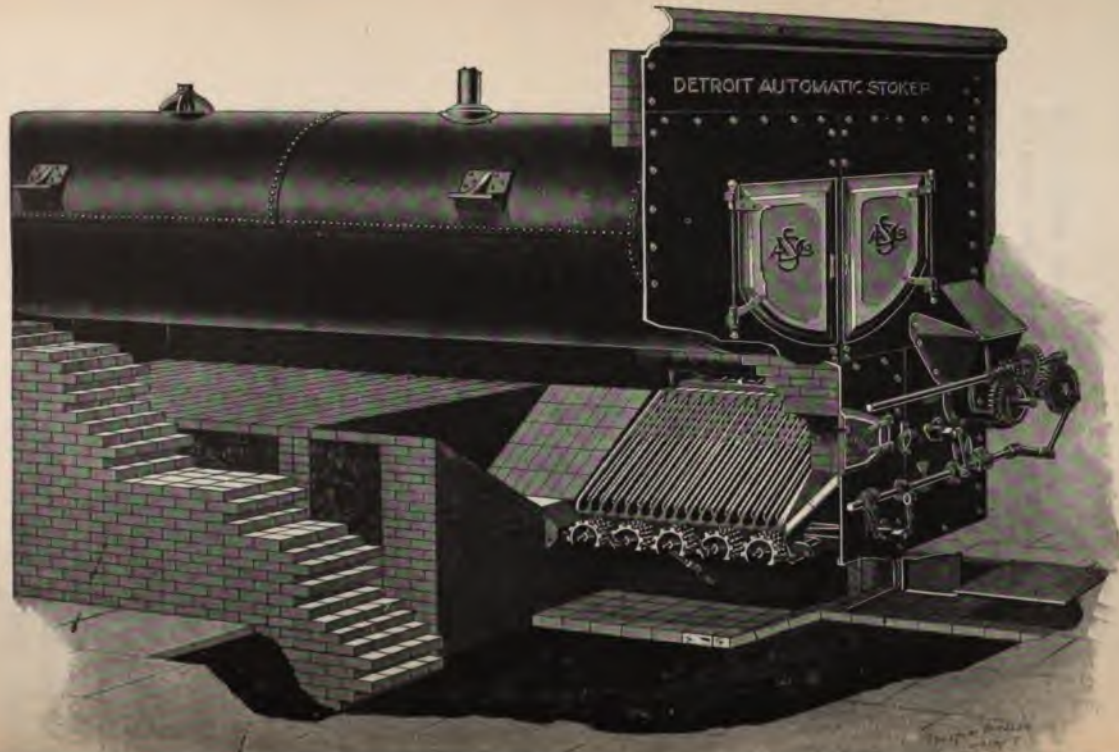
The combining tube C-D is made square on the end so that it can be removed by an ordinary monkey wrench. Be careful that the ring R is not lost; also that it is on the tube in the position as shown in the cuts. Be sure that this tube is not stopped up, and that the small slots and drill holes are clean.

THE DETROIT STOKER.

Construction.—In Fig. 123 is shown a perspective view of this stoker as applied to a horizontal tubular boiler.

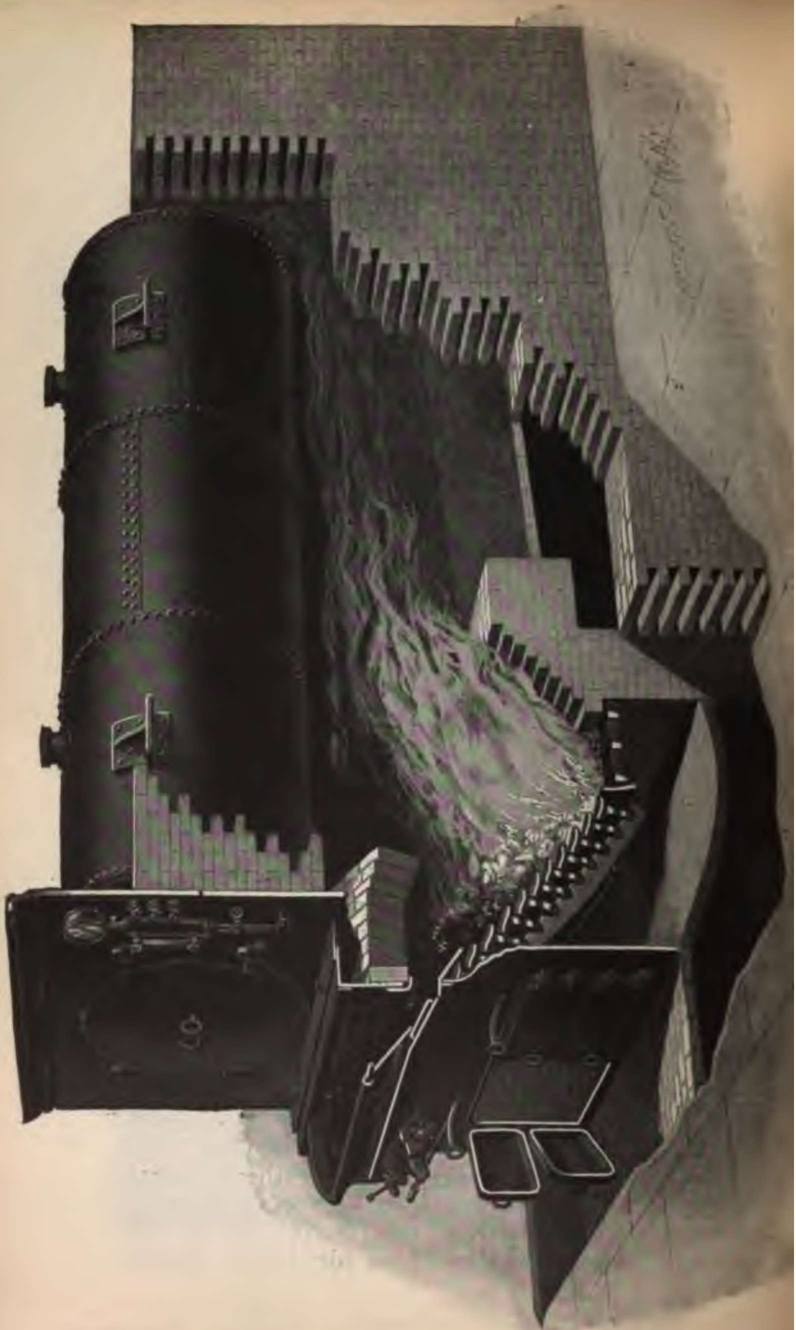
THE RONEY MECHANICAL STOKER.

Construction.—In Fig. 124 is shown a perspective view of this stoker as applied to a horizontal tubular


DETROIT AUTOMATIC STOKER

coal held in the hopper falls in front of the ram at its withdrawal, and at its forward movement is carried up-ward into the furnace, the process being expedited and an equal distribution secured within the retort by the plunger rod with shoes attached which in effect is prac-tically an auxiliary ram. As this operation is continued at intervals, the green coal is always forced upward rom **beneath**, so that in no event does it reach the fire tself in its green state. A restricted application of the rced draft principle is employed in this method of toking, air for combustion being delivered by a blower riven by an auxiliary engine or motor. This air is de-ivered into what is ordinarily termed the ash pit in com-non practice, but which becomes practically a sealed hamber because the space between the upper edge of etort and furnace side walls is covered with cast iron ead plates. The air needed for combustion escapes hrough the tuyeres lining the upper edge of retort and nters the fuel at a point between the green coal and at in an incandescent state. It is at this middle stage at a process of coking is going on, the air combining ith the gases which are being released by the intense at above. As successive charges of green fuel enter e furnace this coked coal is gradually elevated to the ne of perfect combustion and the gases passing up-ard through the fires are consumed. This will account r the thorough manner in which the fuel is burned, ereby securing perfect combustion and a smokeless ack.

A most important feature and one absolutely dis-nctive of this **under-feed system** is the **automatic** regu-lation of fuel supply and air supply. By the use of a very ingenious mechanism the steam controls absolutely the amount of fuel admitted to the furnace, and in the same operation, the quantity of air delivered, always



proportioning these elements to each other and to the load. For instance, if a suddenly imposed load causes the steam pressure to **fall**, the very fact **increases** the rate of feed of fuel and also increases in proper proportion the supply of **air.** If the reverse is the case and the steam pressure suddenly rises, the rate of feed of fuel is **diminished,** likewise the output of air, this reciprocal relation being maintained under all conditions of operation. The result of this close automatic regulation is that only such an amount of fuel is being burned as is **absolutely necessary,** and in a plant subject to intermittent loads the greatest economy in the production of steam must result because the demand for steam is met immediately and with a less expenditure for fuel.

In concluding, the Jones Stoker may be characterized as an apparatus designed to fire a steam boiler most economically, judged from the considerations of saving in fuel, increase in capacity, likewise efficiency, and with considerable reduction in expense for maintenance due to its simple construction.

THE CURTIS DAMPER REGULATOR.

Fig. 126.

Description.—The regulator consists of a composition cylinder, within which is a piston fitted with water packing. The piston rod is connected by a chain, over guide rolls, to the lever of the damper, on which is hung a weight sufficient to overhaul the piston and open the damper, regardless of any ordinary friction.

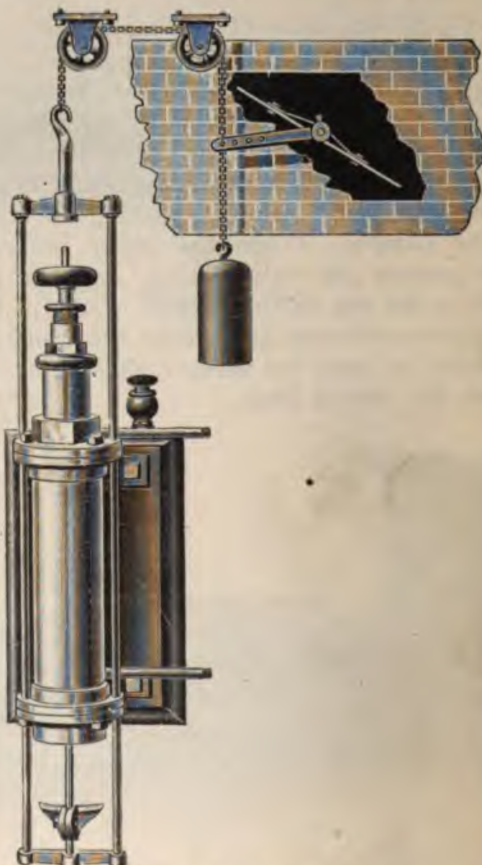
The motion of the piston is controlled by a metallic which operates the valve, alternately closing and opening the damper, as the boiler pressure increases or diminishes. The regulator is fastened to the wall of the boiler room; the top pipe is connected to

Sectional View.

The Jones Under-Feed Stoker.
Fig. 125.

the boiler, and the lower pipe to the drain, ash pit or heater.

The normal condition of the damper is to be wide pen, the weight holding it in that position. To oper- e it, a given load—say 60 pounds to the inch—is pro- iced on the regulator diaphragm by screwing the han- e in. When the pressure in the boiler reaches 60 unds it lifts this load, and permits steam to enter the ice over the piston, slowly pushing it down, and sing the damper. When the boiler pressure falls ow 60 pounds the valve closes, and the pressure, ssing from the top to the bottom of the piston, puts piston in equilibrium and allows the weight, slowly tling down, to open the damper, thus controlling the essure at the desired limit.



The Curtis Damper Regulator.
Fig. 126.

CHAPTER XI.

QUESTIONS AND ANSWERS.

Q. What are the two principal requirements in the management of a boiler?

A. The proper firing of the boiler, and the keeping it clean.

Q. How should a boiler be fired?

A. The fire should be started so as to burn slowly at first, gradually heating all parts of the boiler and settings. In this way strains and injury to the metal is almost entirely avoided.

Q. Why should the boiler be always properly filled with water?

A. In order to keep the water in contact with one side of all metal of the boiler exposed to the fire or heated gases. When iron or steel is heated to more than 600 degrees Fahrenheit it becomes weaker, and it is therefore necessary to keep water in contact with the metal to prevent it attaining this high temperature.

Q. How is a boiler cleaned?

A. The work of cleaning a boiler consists of removing the hand-hole and man-hole plates, the boiler first being emptied. The mud and loose scale is then scraped out, and the whole interior of the boiler thoroughly rinsed out with a hose. Should the scale be too hard to remove this way, it must then be removed with a hammer and chisel, or some other mechanical device.

Q. How often should a boiler be cleaned?

A. This depends largely upon the amount of water the boiler is evaporating, and upon the quality and purity of the water.

Q. What are the principal requirements in the operation of a boiler?

A. Before filling the boiler with water, a careful examination should be made to see that nothing has been left inside of it. The manhole and handhole plates should then be replaced. The boiler should then be filled until the water shows at least half way up in the gauge glass. Then, **and not till then,** should the fire under it be lighted.

Should the boiler be one of a battery of boilers, it should not be cut into service until it has the **same pressure** as the other boiler or boilers. The stop valves should be opened slowly in order to avoid any sudden change in temperature and excessive expansion in the piping. When the boiler or boilers have been cut into service, the feed water for same should next be carefully regulated. Shortly before shutting down for the night, the boiler should be filled to the **top** of the water glass, so as to allow for evaporation or any leakage during the night.

Q. What is meant by priming?

A. It is the water in the boiler being carried over into the steam pipes and thence to the engine.

Q. What are the most common causes of priming?
A. They are (1) insufficient boiler power; (2) defective design of boiler; (3) water carried too high; (4) irregular firing, and (5) sudden opening of stop valve.

Q. What is foaming of a boiler.

A. It is water which is carried over from the boiler the same as in priming, but it is due entirely to the condition of the water. The water does not **lift** in foaming as it does in priming, but simply **foams over,** due to the dirt or grease contained in it.

Q. What is the **only effective** prevention of foaming?

A. The use of **pure** water.

Q. What should be done in case of **foaming?**

A. Check the draft, and cover the fires.

Q. What should be done in case of **low water?**

A. Cover the fire with ashes or green coal, leave the furnace doors open and **close** ash pit doors.

Q. Should the safety valve be opened, the engine stopped or the stop valve closed in such a case?

A. No, simply stop the **source** of the heat.

Q. Should the pump or injector be started or stopped?

A. No, leave them as they are. If they are not running, the sudden introduction of water upon the highly heated plates would cause **too rapid** evaporation of the water. Do not start either until the boiler has had sufficient time to **cool** down.

Q. How often should a boiler be inspected, both externally and internally?

A. At least **once** every year by conscientious and competent officials.

Q. What are the two principal ways of inspecting a boiler?

A. By the **hammer** test, and by the hydrostatic test.

Q. How is the hydrostatic test applied?

A. The boiler is filled full of water and pressure applied by means of a pump, which pressure should be considerably more than the working pressure carried on the boiler.

Q. Why is it necessary that only the pressure required for safety be placed upon the boiler?

A. In order to avoid **straining** the plates.

CHAPTER XII.

BOILERS FOR HEATING PURPOSES.

No branch of engineering has made as rapid strides in the last few years as sanitary engineering, which requires a thorough knowledge of heating and ventilation.

Steam and Hot-Water Heating.— The coal and hot-air furnaces with their expense, dirt and inconveniences, have given way to steam and hot-water systems of heating, affording a luxury to the rich and poor alike which was formerly unknown.

The various systems of heating by steam may be classed: (1) **high-pressure** systems; (2) **low-pressure** systems; (3) **vacuum** or **exhaust** systems.

Under the class of high-pressure systems are all systems that require for heating a greater boiler pressure than 15 pounds per square inch; in the second class are those that operate between 15 pounds boiler pressure and the atmospheric pressure, while in the third class are all systems that work at a lower pressure than the atmosphere; that is, require a partial vacuum for their successful operation. Each of these systems in turn may be subdivided into: (1) the one-pipe system; (2) the two-pipe system; (3) the two-pipe system, with separate return risers; (4) the overhead main, or drop-supply system.

These subdivisions are further subdivided into gravity return systems and forced return systems.

In the **gravity return system** the condensation flows back to the boiler by gravity. To operate this system it is therefore necessary that the full boiler pressure be carried on the entire heating system, which is unsafe and impractical, and it therefore is not much in use.

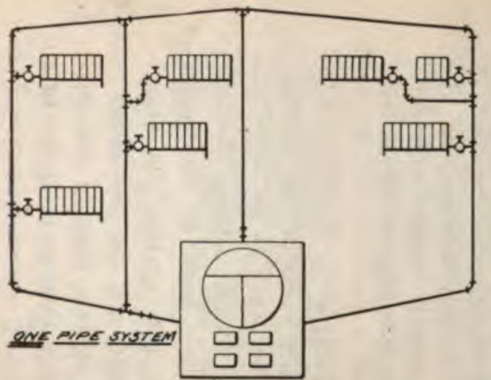
In the **forced return system** the condensation is ɔrced back into the boiler from the return mains of the ystem by the use of a pump, steam trap or steam loop. 'o operate this system a reducing valve is necessary, hich valve is placed on the steam supply pipe to the stem. This system is most generally used, having the lvantage of both safety and economy.

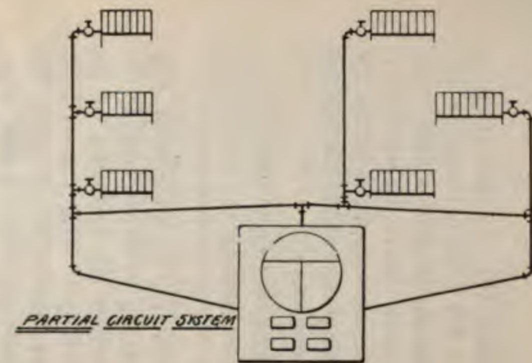
The main difference therefore between steam-heat-g systems, is the method of returning the condensa-ɔn to the boiler.

One-Pipe System.—This system, as shown in Fig. 27, is the simplest form of heating systems, and is the stem now universally used, when the building or the ɔace to be heated is not too large. The steam from ıe boiler is carried to the risers through one pipe, the ɔndensation flowing back through the **same pipe,** hereby causing the steam and condensation to move in pposite directions, which is a disadvantage, as the team becoming wet, may cause a "water hammer." Vith proper installation, and by keeping all valves wide pen, this can be avoided.

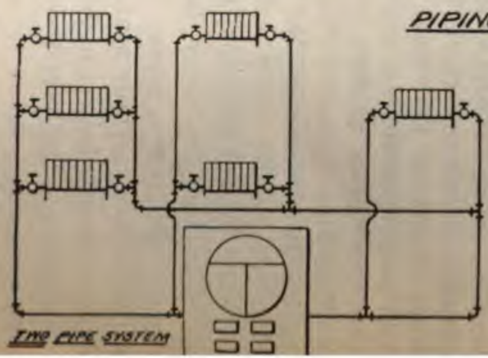
Two-Pipe System.—This system, as shown in Fig. 27, has two connections for each radiator, one serving s an inlet for the steam and the other as an outlet for he water of condensation, the steam passing through ne pipe and the water flowing back to the boiler hrough the return pipes. In this system the steam nd water are carefully **separated,** and the circulation is herefore much better in this system than in the one-ipe system. The principal objection to it, is its **first ɔst.**

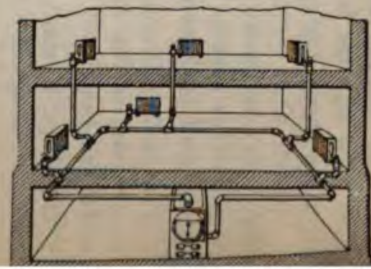
The Separate Return System.—The only difference ı this system from the ordinary two-pipe system is that





PIPING FOR STEAM HEATING SYSTEMS.





each radiator is provided with its own separate return pipe.

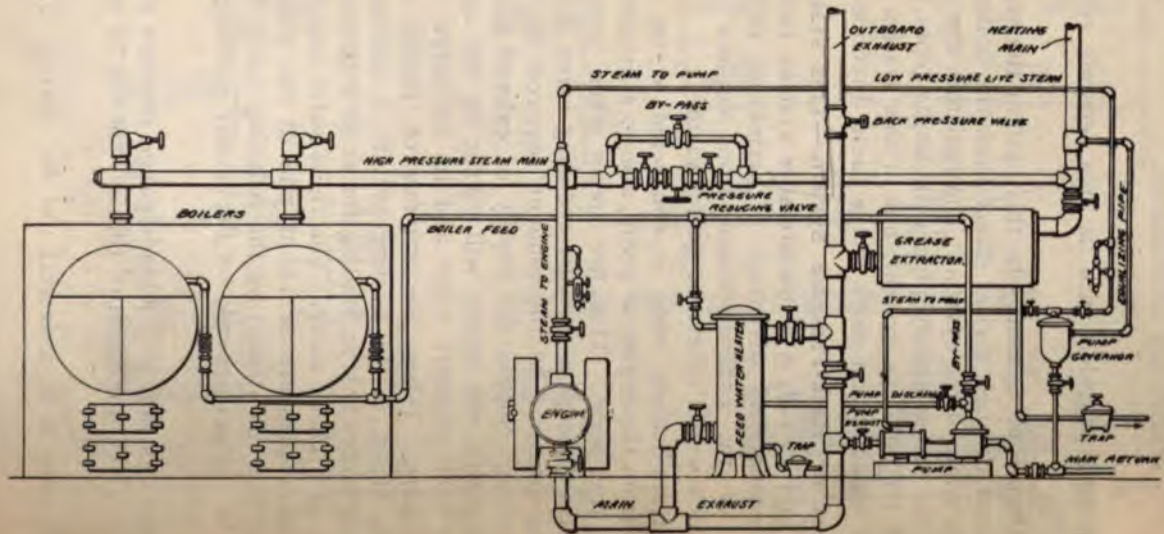
The Drop-Pipe System.—In this system the steam supply passes through a riser direct from the boiler to the highest point of the system. The radiators are connected to the steam supply pipe with single pipes, the same as in the one-pipe system; but in this system the steam and condensation move in the same direction.

Exhaust or Back-Pressure System.—This system, as shown in Fig. 128, is a **low-pressure** system, having the great economical advantage of permitting of the utilization of the exhaust steam from engines and pumps, which would otherwise go to waste.

The steam-heating main is connected to the exhaust pipe from the engine or pump, also to a live steam pipe from the boiler. This live steam when used is made to pass through a pressure reducing valve, which reduces the pressure to the amount required for the heating system. Should the supply of exhaust steam become excessive, the excess will escape by the opening of the back pressure valve and its discharge into the atmosphere. When the engines or pumps are stopped the steam in the heating system is prevented from passing backwards and filling the same with water, by the use of a check valve. The relief valve is set to blow off at a pressure of about one or two pounds higher than that maintained by the reducing valve. The safety of the system depends on the proper working of this relief valve.

As exhaust steam at 5 pounds gauge pressure contains 971 B. T. U., the merit of this system can at once be seen.

This system is in universal use for heating large



Back Pressure Heating System.

Fig. 128.

office buildings and entire business districts where access can be had to **steam power plants.**

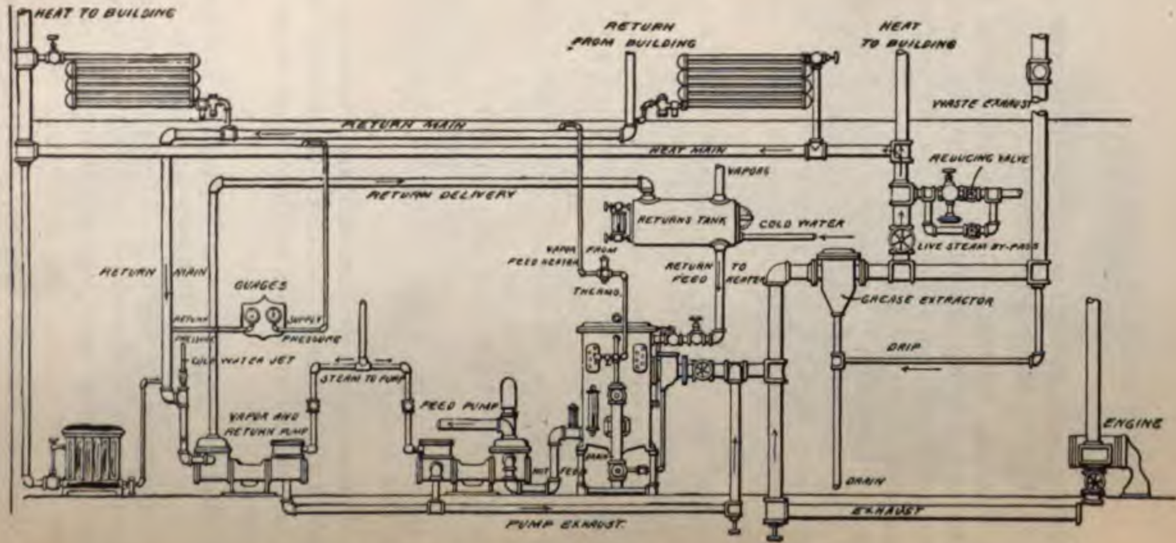
The Vacuum System.—This system differs from the exhaust system just described in that its operation causes no additional back pressure on the engine or pump, but removes at least a part of the back pressure from same, as a **vacuum** is constantly maintained on the returns. This further permits this system to be operated either as a **high** or low pressure system, and to secure its steam supply from any source, either as exhaust or live steam.

Generally, the system is operated with **exhaust steam,** a two-pipe system being used. The returns are connected to a receiver, which collects the air and water in the system. To this receiver is connected a vacuum pump, which removes all the air and water in the system, and maintains a vacuum at any desired degree. This pump only removes the air and water from the system, which are discharged into an open tank, permitting the air to escape, and the water remaining is pumped back into the boiler, using an ordinary feed pump for this purpose.

The **thermostatic** valves which are placed on the return end of each radiator to open automatically when water or air passes, are made to close when steam begins to pass.

With this system steam can be used at a temperature as low as 140 degrees Fahrenheit, and at the same time the capacity of the engine to do work is increased. As the temperature of the steam used in this system is lower than in other systems, the radiators must be proportionately larger.

The Webster Vacuum System, which is shown in



The Webster Vacuum Heating System.
Fig. 129.

129, is one of the best vacuum systems on the t.

lot-Water Heating.—Hot-water systems are very r to the steam systems described, except that **hot** flows through the pipes and radiators, instead of . The hot-water system has the great advantage, gh, of the ease of **regulation** of the temperature. a steam system, it is necessary to regulate the erature by turning on or off the steam **entirely,** h causes either too high or too low a temperature, ss operated carefully.

With a hot-water system the radiators can be kept ed on at all times, the regulation of temperature g secured by varying the **temperature** of the **water** ing through them. There are two distinct hot-er systems of circulation employed, one depending the difference in temperature of the water in the out-and return pipes, called **gravity circulation**; and the r called the **forced circulation** system, in which a np is employed to force the water through the mains. first, or "gravity circulation" system, is used for llings and small buildings, and the latter system for e **buildings,** and wherever there are a **long run** of ns. For the first system usually a sectional cast iron er is employed, although any type of boiler may be loyed. In the second or "forced circulation" sys-, a heater to warm the water, and a centrifugal or ry pump is used. Fig. 130 is a type of a sectional cast boiler. These boilers should be regularly in-cted, for no boiler under pressure, however small pressure may be, is perfectly safe. The only per-tly safe boiler is one which has no fire under it.

A system for hot-water heating costs more to in-ll than a steam-heating system, owing to the differ-

The American Radiator for Steam Heating.
Fig. 131.

the room to be warmed, where direct radiation is ed:

Bathrooms and living-rooms with three exposed alls and a large amount of glass surface, require an lowance of 1 square foot for each 40 cubic feet.

Bathrooms and living-rooms with two exposed alls and a large amount of glass surface, require an al-wance of 1 square foot for each 50 cubic feet.

Bathrooms and living-rooms with one exposed wall d an ordinary amount of glass surface, require an al-wance of 1 square foot for each 60 cubic feet.

Sleeping rooms require an allowance of 1 square ot for each 60 or 70 cubic feet.

Halls require an allowance of 1 square foot for each to 70 cubic feet.

School rooms require an allowance of 1 square foot r each 60 to 80 cubic feet.

Churches and auditoriums having large cubical con-nts and high ceilings, require an allowance of 1 square ot for each 65 to 100 cubic feet.

Lofts, workshops and factories require an allowance 1 square foot for each 75 to 150 cubic feet.

For **indirect radiators** allow at least 50 per cent re surface.

No heating system can be successfully operated thout **steam traps** of sufficient capacity to remove all condensation.

The water of condensation in a steam-heating sys-is led into the steam trap and thence allowed to through a "cooling coil," before being discharged the drainage system.

Under ordinary conditions for steam heating, one se power will heat in brick buildings 15,000 to 20,000 ic feet; in brick stores, 10,000 to 15,000 cubic feet;

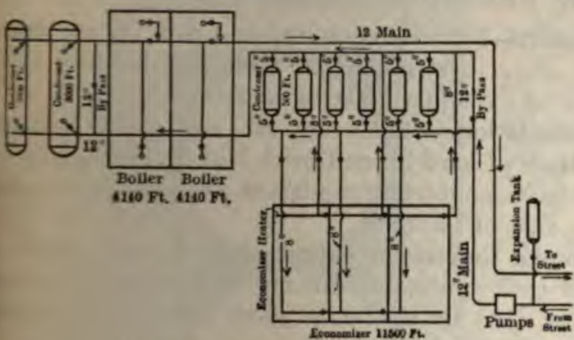
in brick dwellings, 10,000 to 15,000 cubic feet; in brick churches, brick shops, etc., 8,000 to 12,000 cubic feet wooden dwellings, 8,000 to 10,000 cubic feet.

Where the exhaust steam is used in connection with a hot-water system, the water to be warmed i heated by the steam in large heaters, similar to feed water heaters, and circulated through the mains b means of centrifugal pumps.

Central Station Heating.—Where large districts a to be heated, a central heating station becomes nece sary, the steam or hot-water mains from same being la **underground,** through the streets. Both steam and h water are used for this character of heating, but it generally admitted that where the district is large that t **hot-water** systems are the best as there is much less lo from condensation in the mains, and the temperature c be much better regulated. As the exhaust steam fro some large plants is generally used in connection wi either of these systems, the central heating plant shou be located as near as possible to it, and the exhau steam conveyed through an underground duct in as rect a path as possible. The equipment of the stati depends largely upon the extent of the district to heated, it being usual to allow for steam heating square foot of boiler heating surface for supplying square feet of radiating surface, or one boiler ho power to each 120 to 200 square feet of radiating s face, depending upon whether steam or hot water used.

Fig. 132 shows a complete installation of a cent station heating plant.

Insulation and Cost.—The **underground distribut system mains** in either system must be properly ins ated, or the loss by condensation will be very great.



Central Station Heating Plant.
Fig. 132.

Fig. 133 shows a form of insulation which has proved quite satisfactory. Using this insulation, the hot water has been sent out through a two-pipe balanced system six and one-half miles or thirteen miles out and returning, with a loss of only 30 degrees, the water being sent out at a temperature of 170 degrees, and returning at 140 degrees.

SPECIFICATIONS AND CONTRACT FOR A LOW PRESSURE STEAM HEATING PLANT.

Boiler.—Furnish complete and set up in basement one .... steam boiler having a heating capacity equal to 3,400 square feet of radiation.

Foundation.—Boiler to set on good substantial foundation of hard burned brick laid in Portland cement, or to have concrete foundation of proper dimensions to suit size of boiler.

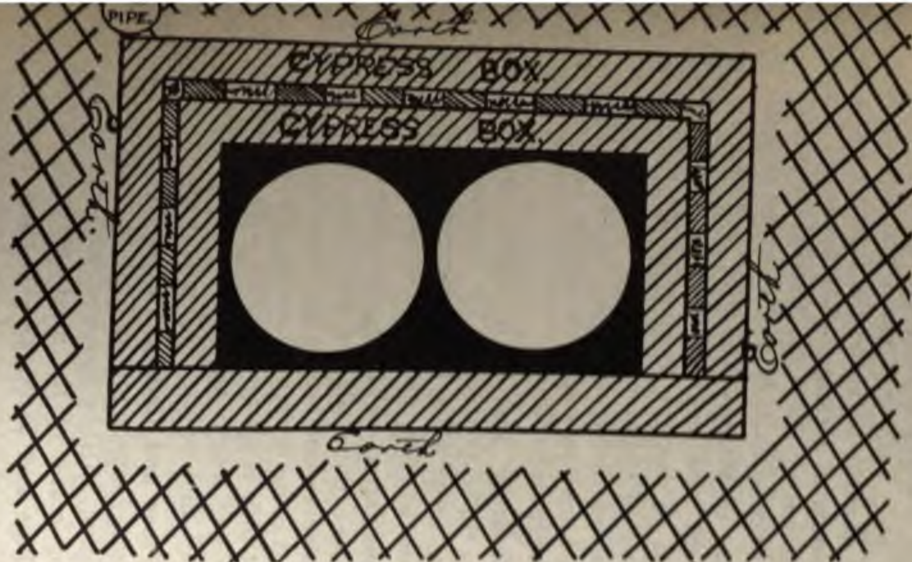
Smoke Connection.—Furnish and erect smoke connection from boiler to chimney of number .... iron of sufficient size to insure a good draft with necessary damper and check door.

Grate Bars.—Furnish and set with boiler a full set of improved grate bars.

Trimmings.—Furnish and connect to boiler all necessary fixtures and trimmings called for by manufacturer of boiler, consisting of safety valves, low pressure steam gauge, combination body with connections to boiler, suitable blow-off valves, feed water and check valve.

Firing Tools.—Furnish and set with boiler a full set of firing tools consisting of poker, hoe, slice bar, flue brush and scoop shovel.

Automatic Damper Regulator.—Set up and properly connect with boiler, one automatic damper regu-



Insulation for Two-Pipe Heating System.
Fig. 133.

lator or diaphragm, to be placed on top of boiler and shall be connected to draft door and check draft in smoke pipe with iron chain for the admission of the proper quantity of air to the fire to govern the steam.

System of Heating.—The system of heating will be that known as the Low Pressure Gravity System, all water of condensation to be returned to boiler by gravity.

Size of Mains.—The size and general run of all basement and riser pipes to be such as to be best adapted to suit the location of the radiators. All connections to radiators, branch supply pipes and the entire piping throughout shall be ample in size to insure a rapid and noiseless circulation of steam throughout the entire apparatus.

Securing Pipe.—All piping shall be constructed with proper provisions for expansion and contraction, all basement pipes to be secured on neat cast iron expansion hangers placed at proper intervals.

Insulation.—Where pipes pass through partitions in basement, there shall in each case be provided wrought iron sleeves one size larger than the pipe they are used on and come flush with walls; where pipes pass through floors they must be provided with wrought iron sleeves of proper length and size, same to make a neat finish at floor and ceiling.

Floor and Ceiling Plates.—All pipes on riser and radiator connections and all pipes in finished parts of basement, shall be provided with neat cast iron floor and ceiling plates of the most approved pattern.

Pipe and Fittings.—All pipes used in the erection of this work shall be of the best make and of standard weight and sizes; all pipe over 1¼ inches in size to be lap-welded. All fittings used shall be fine grained grey cast iron with clean cut taper threads.

erials and Workmanship.—All materials enter- the construction of this apparatus, whether or not, shall be the best of their respective nd all put together by skilled mechanics under nediate supervision.

ves on Radiators.—Each radiator shall be oper- but one valve, which shall be of the best steam extra heavy, with Jenkins disc, to have Union g Joint, to be heavy nickeled all over and have d hardwood handles.

Valves.—Each radiator and end of heating main e provided with an automatic nickel plated air guaranteed not to throw water.

lves and Check Valves.—All globe, gate and valves 2 inches in size or smaller to be made of heavy steam metal; all valves 2½ inches in size ger to have iron body with brass trimmings.

nish of Radiators.—All radiators are to be fin- in colors selected by architect or owner. All ex- pipes above cellar to be finished same as radi- all pipes in basement and boiler room to be d with best Asphaltum varnish.

equirements of Owner.—Owner shall provide ng for the admission of boiler and space in boiler for the erection of same. Owner to provide water sewer connection in boiler room near boiler and ney of sufficient size.

Cutting and Repairing.—We will do all necessary g and repairing for the admission of our work, and ve all debris connected with our work.

Guarantee.—We guarantee to heat all rooms and specified to be heated as stipulated in schedule of ation to 70 degrees when the thermometer is zero the outside with a pressure not exceeding 5 pounds.

We further guarantee to fill the whole system with one pound of steam on boiler, and the working of the apparatus to be absolutely noiseless and the apparatus to be free from all leaks or imperfections.

Radiation.—The radiating surface shall consist of ornamental cast iron radiators of most approved design, and shall be placed in position for obtaining the best results in numbers, sizes and heights. Total amount of radiation to be not less than 2,415 square feet divided into 75 radiators.

SPECIFICATIONS FOR A COMPLETE CENTRAL HEATING PLANT.

General.—These specifications are intended to cover a complete heating plant in all details, and if, in these specifications, anything is needed to make the plant complete in accordance with the intent hereof, then in that case it shall be furnished by the contractor without any further charge to the purchaser.

Definition.—Whenever the word "purchaser" is hereinafter referred to, it shall be understood to mean the ....Heating Company, of .... Whenever a "contractor" is hereinafter referred to, it shall be understood to mean the .... of .... Whenever a classification hereinunder is specified and no mention is made of either the purchaser or contractor, it shall be understood that the contractor is to do the described work.

Real Estate.—A piece or parcel of land shall be furnished by the contractor to the purchaser, the same to be located ....

Power House.—Upon the above described piece of real estate there shall be installed a substantial brick

wer house by the contractor, the same to be of neat sign and suitable for the purpose of building therein e necessary appurtenances for a complete central ition heating plant.

Boilers.—There shall be installed a sufficient ount of heating surface, the same to be divided into e number of units adapted for the work, sufficient ating surface, together with exhaust steam which is be furnished to the plant by the company from the ower house of the railway and electric company, suffient capacity to handle at 10 degrees above zero ...... are feet of radiation, the same being operated with hot water circulation. The above described boilers all be of the .... or some other water e type equally as good. They shall be equipped with king grates and the necessary tools for the firing of e same.

Smoke Stack.—A smoke stack of the proper diamer and height shall be installed for each battery of two ilers. Same shall be carried from the top of the ler settings and maintained by a guy stub set in the per position.

Boiler Feed Pumps.—There shall be furnished two nze fitted boiler feed pumps; each pump should have ficient capacity to handle the entire plant with a pis- speed not to exceed 100 feet per minute.

Feed-Water Heater.—There shall be furnished a d-water heater and purifier of sufficient capacity to nish boiler feed water for the number of boilers that l be necessary for the operation of the plant in ques- n. It shall also be of sufficient size to purify the ter used in the heating system.

Circulating Pump.—There shall be furnished two nze-fitted special designed hot water circulating

pumps, to be used for the purpose of circulating the water in the heating system. They shall have a capacity of not less than fifteen gallons of water each per minute. They shall be erected upon the proper foundations by the contractor and equipped with automatic governors.

Placing, Regulating and Receiving Pumps.—There shall be furnished the necessary pumps, the same erected upon foundations and equipped with an automatic governor to relieve the apparatus from condensation, maintain the necessary vacuum on the system, and to make the plant complete in all its details.

Vacuum Pumps.—There shall be installed a vacuum pump of sufficient capacity, the same to be bronze-fitted throughout, to handle the exhaust steam which is to be received from the .... plant. Same shall be erected complete upon foundation to be furnished by the contractor.

Condensers.—There shall be furnished two condensers, being of ...... feet size. The same shall be delivered and erected complete upon foundations furnished by the contractor.

Pipe Connections.—The contractor shall furnish all necessary valves, fittings, pipe, labor, etc., so as to connect up all the above described apparatus so as to be complete in all its details and in a good and workmanlike manner.

Pipe Covering.—After all of the apparatus has been installed and connected, all pipe and fitting shall be covered with an approved pipe covering.

Air Compressor.—There shall be furnished one air compressor, same having a capacity of ...... feet of free air per minute. The same shall be equipped with the necessary regulators, storage tanks, etc.

Gauge Boards.—There shall be furnished one marble gauge board, the same having mounted thereon all the necessary gauges, thermometers, etc., for the indicating of the proper working of the system.

Pipe Line.—The pipe line to be laid in the various streets in the city of .... shall be laid by the contractor and shall consist of the following pipe lines:

...... feet 14-inch main.
...... feet of 12-inch main.
...... feet of 10-inch main.
...... feet of 8-inch main.

...... feet of main which shall be of such average sizes so as to equal the cost of 6-inch main.

Location of Mains.—The mains shall be located in such parts of the streets as found convenient on account of construction conditions. The mains shall be so laid as to have a cover of earth of at least two feet, excepting in such places as obstructions are encountered; then, in that case, the minimum depth from surface of street to top of insulation shall be at least 12 inches.

Materials.—The materials to be used in the construction of the pipe lines in question, shall consist of lumber of the proper thickness and lengths, the same to be of a first-class quality.

The pipe shall be of standard wrought full-weight pipe, of the Crane or National Tube Company's manufacture, or something equally as good. All fittings shall be of standard grey iron and true as to weights, etc. The pipe lines shall be protected throughout with a system of valves and expansion joints. Wherever valves or expansion joints are put into the system, they shall be surrounded with a brick manhole with a cast iron top, so as to permit of free access to the same

The expansion joints shall be so arranged that the will not be any undue strain on any of the fittings the system.

Service Openings.—Service openings shall be ma in the system as needed to provide for the taking o of service connections. They shall average at least o to every 100 feet of main.

Test.—As the street work is installed, it shall tested, so as to be tight under a pressure of not le than 60 pounds.

Re-Paving.—Whenever any of the lines are laid streets which have been paved, the pavement shall replaced in as good a condition as found.

Time of Completion.—The work herein conte plated shall be completed and in full running order ...., in accordance wi the minimum terms of the franchise.

Finally.—During the construction of the plant t contractor shall furnish all the engineers and superi tendents necessary for the complete building of t plant, together with the measuring of the buildings a making of contracts for the heating of the buildin As soon as the plan is ready for operation, the pu chaser shall measure all buildings and make all heati contracts and shall provide the necessary attendants the operation of the plant, together with all the nec sary fuels and materials for the proper operation of t same. The contractors shall furnish for a period thirty (30) days, if necessary, an expert to instruct t superintendent of the heating company in the pro management and operation of the plant.

Guarantees.—The contractor guarantees the shall be complete in all details and operate succes as a central station heating plant, and any defec

ing in one year shall be replaced by contractor out expense to purchaser.

System.—The system shall be what is known as ...., and shall uilt under the direction of ....

LES FOR JANITORS AND FIREMEN HAVING CHARGE OF LOW PRESSURE STEAM HEATING BOILERS.

rtford Steam Boiler Inspection and Insurance Co.

1. **Getting Ready to Start.**—The attendant should that all joints are properly packed, and that none leak filling the boiler with water. The gauge cocks, er gauge, and safety valve should be carefully exam- l that all are free and in good order. All valves in ing and radiators and air valves, should be examined l seen to be in order, and that all necessary packing repairs have been done.

2. **Condition of Water.**—The first duty of an engi- r when he enters his boiler room in the morning is ascertain how many gauges of water there are in his lers. Never unbank or replenish the fires until this done. Accidents have occurred and many boilers ied from neglect of this precaution.

3. **Raising Steam and Management of Valves.**— l steam and return pipes should be closed before fires e started. When steam has been raised to working ssure, the steam valves should be opened very slowly. ter the boiler pressure is established in the pipes the rn valves can be opened, allowing the water of con- nsation to flow back to the boiler. Whenever neces- ry to shut off at the boiler or any section of heating stem, the return or drip valves should be closed first d then the steam valves. In letting on the steam the

supply or steam valves should be first opened an the return or drip valves. This caution is import

4. **Low Water.**—In case of low water, imme cover the fires with ashes, or if no ashes are at ha fresh coal and shut the ash pit and open the fire Do not turn on the feed under any circumstan tamper with or open the safety valves. Let the outlets remain as they are.

5. **Feeding.**—When necessary to take fresh the boiler should be fed as slowly as possible to unnecessary contraction and leakage at joints.

6. **Gauge Cocks and Water Gauge.**—Keep cocks clean and in constant use. Glass gauges not be relied upon altogether.

7. **Safety Valves.**—Raise the safety valve tiously and frequently, as they are liable to becor in their seats.

8. **Safety Valve, Automatic Regulator, and Gauge.**—Should the gauge at any time indicate th of pressure to which the regulator is adjusted its controlling the draft, the regulator should be ined and disconnected from the damper or draf If the regulator works quickly and well the tro in the damper or draft door, and it should at o cleaned and made to work freely. Should the re fail to work, or work very slowly, the pipe con to the boiler is choked and should be cleaned. S pressure gauge, regulator, and safety valve ag case of difference, notify the company's inspector

9. **Clean Plates and Heating Surfaces.**—Pa attention should be taken to keep plates and p boilers exposed to the fire perfectly clean. Al tubes, flues, and connections well swept. This ticularly necessary in many types of small heatin

with large heating surfaces and small heat passages, they soon foul if neglected. Strict attenion to this is necessary for full economy and capacity of boilers.

10. **Blowing Off.**—If necessary to blow down during the season, the fires should be hauled and furnaces and bridge wall cleaned at least two hours before blowing down. Allow the boiler to stand until cool before filling with cold water.

11. **Laying up Boilers for the Season.**—Haul fires, clean furnaces, and run off the water while hot. Thoroughly clean all heating surfaces at once. Remove hand and manhole plates, dry out water if any remains, and leave the boiler thoroughly clean and dry. Drain all water from return drip pipes. All good systems are provided with drip cocks at lowest point in return pipes for this purpose. During the summer see that no water or drip or moisture collect in or around the boiler.

12. **Piping, Radiators, and Settings.**—Mark all joints that have shown signs of leakage and need packing; also air cocks and valves and anything that may need repairs before using another season. If repairs are needed to boiler settings see what they are and have them made while boiler is idle.

CHAPTER XIII.

BOILER TRIALS.

Horse Power and Efficiency Tests.—The horse power of a boiler is entirely a measure of **evaporation**, and not of power as the term would lead one to believe.

Unit.—One boiler horse power as has been previously defined, is equivalent to the evaporation of 34.48 pounds of water from and at 212 degrees Fahrenheit or practically 34½ pounds of water per hour, which is the same as the evaporation of 30 pounds of water per hour from feed water having a temperature of 100 degrees Fahrenheit into steam at 70 pounds pressure.

Standard.—It is usual to express the evaporation of the water in the boiler from and at 212 degrees Fahrenheit, instead of from 100 degrees Fahrenheit at a steam pressure of 70 pounds, as this is the **standard boiler horse power** recommended by the American Society of Mechanical Engineers.

Commercial Rating of Boilers.—This society, which is recognized as the **highest authority** on all subjects pertaining to mechanical engineering, further recommended as follows:

"A boiler rated at any stated capacity should develop that capacity when using the best coal ordinarily sold in the market where the boiler is located, when fired by an ordinary fireman without forcing the fires, while exhibiting good economy; and further that the boiler should develop at least **one-third more** than the stated capacity when using the same fuel and operated by the same fireman, full draft being employed and the fires being crowded; the available draft at the damper,

ıless otherwise understood, being not less than ½-inch ater column."

Efficiency.—By the efficiency of a boiler is meant ıe ratio between the heat units **utilized** in the producon of steam, and the heat units **contained** in the fuel ıed.

In order to determine the horse power and the effiıency of a boiler, all boilers must be tested under the me **set of rules**, so that the conditions will be exactly e same.

Code of Rules.—In order to obtain such **uniformity**, e American Society of Mechanical Engineers appointed committee to formulate a set of rules which would btain such results, and in 1885 the report of this comittee was accepted. This code of rules was revised in 99, and since then have been universally adopted for boiler trials or tests.

These rules provide for the method of conducting boiler trials, from the very simplest to the most elabrate.

Purpose of Boiler Trials.—While there are several rposes for which boiler trials may be conducted, the st usual and important are for determining—

(1) The **standard horse power** of a boiler accordg to the rating of the American Society of Mechanical gineers.

(2) The **efficiency** of the boiler.

In addition to these two principal purposes, boiler ls are also conducted for the purposes of determin-

(3) The **steam making value of a fuel** as measured ounds of water evaporated per pounds of fuel.

(4) The **coal and steam consumption** in pounds per ated **engine horse power** per hour.

STATE.	Kind of Coal.	Per Cent of Ash.	In Heat, Units per Pound.	In Pounds of Water Evaporation.	Percentage of Incombustile Matter.	Heat Units Available for Steam-making.	Horse Power for 1 pound of Coal.	Evap. 100. Per Cent.
Pennsylvania,	Anthracite,	3.49	14.199	14.70	0	14.500	5.074	15.01
Pennsylvania,	Anthracite,	6.13	13.535	14.01	1	14.355	5.647	14.86
Pennsylvania,	Anthracite,	2.90	14.221	14.72	2	14.210	5.590	14.60
Pennsylvania,	Cannel,	15.02	13.143	13.60	3	14.065	5.533	14.44
Pennsylvania,	Conelsville,	6.50	13.368	13.84	4	13.920	5.436	14.40
Pennsylvania,	Semi-bituminous,	10.77	13.155	13.62	5	13.775	5.418	14.25
Pennsylvania,	Stone's Gas,	5.00	14.021	14.51	6	13.630	5.361	14.10
Pennsylvania,	Youghiogheny,	5.60	14.265	14.76	7	13.485	5.305	13.94
Pennsylvania,	Brown,	9.50	12.324	12.75	8	13.340	5.243	13.80
Kentucky,	Caking,	2.75	14.391	14.89	9	13.195	5.190	13.65
Kentucky,	Cannel,	2.00	15.198	16.76	10	13.050	5.133	13.51
Kentucky,	Cannel,	14.80	13.360	13.84	11	12.905	5.706	13.35
Kentucky,	Lignite,	7.00	9.326	9.65	12	12.760	5.019	13.20
Illinois,	Bureau Co.,	5.20	13.025	13.48	13	12.615	4.962	13.05
Illinois,	Mercer Co.,	5.60	13.123	13.58	14	12.470	4.905	12.90
Illinois,	Montauk,	5.50	12.659	13.10	15	12.325	4.848	12.75
Indiana,	Block,	2.50	13.588	14.38	16	12.180	4.791	12.60
Indiana,	Caking,	5.66	14.146	14.64	17	12.035	4.743	12.45
Indiana,	Cannel,	6.00	13.097	13.56	18	11.890	4.637	12.30
Maryland,	Cumberland,	13.98	12.226	12.65	19	11.745	4,659	12.18
Arkansas,	Lignite,	5.00	9.215	9.54	20	11.600	4.563	12.00
Colorado,	Lignite,	9.25	13.562	14.04	21	11.455	4.545	11.85

n be determined. To do this it is necessary to ie **evaporation** to a basis common to all, called **valent evaporation from and at 212 degrees eit.** The necessity of this can be seen as boil-t evaporate all the water pumped into them into rated steam, and hence the **actual** evaporation eatly with the different character and construc-oilers. In order to ascertain the actual evap-t is therefore necessary that the feed water be d by some number or factor representing the of **dry steam** contained in every pound of feed aporated. Such numbers, or factors, are called f **evaporation,** and by their use the actual evap-f the boiler is readily reduced to the equivalent ion from and at 212 degrees Fahrenheit.

'able No. 13 is given factors of evaporation for d gauge pressures.

tors of Evaporation.—Therefore, to find the nt evaporation of any boiler, multiply the actual ion by the factor of evaporation. These fac-vaporation can be found in most all engineering imilar to the adjoining table of **Factors of Evap-**

STEAM PRESSURE BY GAUGE.

Temp're of Feed Water Deg. Fahr.	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300
32	1.214	1.216	1.220	1.222	1.225	1.227	1.229	1.231	1.232	1.234	1.236	1.237	1.239	1.240	1.241	1.243	1.244	1.245	1.246	1.247	1.248	1.250	1.251	1.252	1.253	1.254
40	1.206	1.209	1.212	1.214	1.216	1.219	1.220	1.222	1.224	1.226	1.227	1.229	1.230	1.232	1.233	1.234	1.236	1.237	1.238	1.239	1.240	1.241	1.242	1.243	1.244	1.245
50	1.195	1.197	1.201	1.204	1.206	1.208	1.210	1.212	1.214	1.215	1.217	1.218	1.220	1.221	1.223	1.224	1.225	1.226	1.228	1.229	1.230	1.231	1.232	1.233	1.234	1.235
60	1.185	1.188	1.191	1.193	1.196	1.198	1.200	1.202	1.203	1.205	1.207	1.208	1.210	1.211	1.212	1.214	1.215	1.216	1.217	1.218	1.219	1.220	1.221	1.222	1.223	1.224
70	1.175	1.178	1.180	1.183	1.185	1.187	1.189	1.191	1.193	1.194	1.196	1.197	1.199	1.200	1.202	1.203	1.205	1.206	1.207	1.208	1.209	1.210	1.211	1.212	1.213	1.214
80	1.164	1.167	1.170	1.173	1.175	1.177	1.179	1.181	1.183	1.184	1.186	1.187	1.189	1.190	1.192	1.193	1.194	1.195	1.196	1.198	1.199	1.200	1.201	1.202	1.203	1.204
90	1.154	1.157	1.160	1.162	1.165	1.167	1.169	1.170	1.17[illegible]	1.174	1.176	1.177	1.179	1.180	1.181	1.183	1.184	1.185	1.186	1.187	1.188	1.189	1.190	1.191	1.192	1.193
100	1.144	1.147	1.150	1.152	1.154	1.156	1.158	1.160	1.162	1.164	1.165	1.167	1.168	1.170	1.171	1.172	1.174	1.175	1.176	1.177	1.178	1.179	1.180	1.181	1.182	1.183
110	1.133	1.136	1.139	1.142	1.144	1.146	1.148	1.150	1.152	1.153	1.155	1.156	1.158	1.159	1.160	1.162	1.163	1.164	1.166	1.167	1.168	1.169	1.170	1.171	1.172	1.173
120	1.123	1.126	1.129	1.131	1.133	1.136	1.138	1.140	1.141	1.143	1.145	1.146	1.147	1.149	1.150	1.151	1.153	1.154	1.155	1.156	1.157	1.158	1.159	1.160	1.161	1.162
130	1.113	1.116	1.118	1.121	1.123	1.125	1.127	1.129	1.130	1.132	1.134	1.136	1.137	1.138	1.140	1.141	1.142	1.144	1.145	1.146	1.147	1.148	1.149	1.150	1.151	1.152
140	1.102	1.105	1.108	1.110	1.113	1.115	1.117	1.119	1.120	1.122	1.124	1.125	1.127	1.128	1.129	1.131	1.132	1.133	1.134	1.135	1.136	1.137	1.138	1.139	1.140	1.141
150	1.091	1.095	1.098	1.100	1.102	1.104	1.106	1.108	1.110	1.111	1.113	1.115	1.116	1.118	1.119	1.120	1.121	1.123	1.124	1.125	1.126	1.127	1.128	1.129	1.130	1.131
160	1.081	1.084	1.087	1.090	1.092	1.094	1.096	1.098	1.100	1.101	1.103	1.104	1.106	1.107	1.108	1.110	1.111	1.112	1.113	1.115	1.116	1.117	1.118	1.119	1.120	1.121
170	1.070	1.074	1.077	1.079	1.081	1.083	1.085	1.087	1.089	1.091	1.092	1.094	1.095	1.097	1.098	1.099	1.101	1.102	1.103	1.104	1.105	1.106	1.107	1.108	1.109	1.110
180	1.060	1.063	1.066	1.069	1.071	1.073	1.075	1.077	1.079	1.080	1.082	1.083	1.085	1.086	1.088	1.089	1.090	1.091	1.093	1.094	1.095	1.096	1.097	1.098	1.099	1.100
190	1.050	1.053	1.056	1.058	1.060	1.063	1.065	1.066	1.068	1.070	1.071	1.073	1.074	1.076	1.077	1.078	1.080	1.081	1.082	1.083	1.084	1.085	1.086	1.087	1.088	1.089
200	1.039	1.043	1.045	1.048	1.050	1.052	1.054	1.056	1.058	1.059	1.061	1.063	1.064	1.065	1.067	1.068	1.069	1.071	1.072	1.073	1.074	1.075	1.076	1.077	1.078	1.079
210	1.029	1.032	1.035	1.037	1.040	1.042	1.044	1.046	1.047	1.049	1.051	1.052	1.053	1.055	1.056	1.057	1.059	1.060	1.061	1.062	1.063	1.064	1.065	1.066	1.067	1.068

Factors of Evaporation.
Table No. 13.

Solution.—In the Table of Factors of Evaporation opposite the 50 degrees temperature of the feed water and boiler pressure of 100 pounds, we find the factor 1.20. Now multiply the quantity of water actually evaporated, viz.: 5,000 pounds by this factor of 1.20, and the result will be the water evaporated per hour from and at 212 degrees, viz.: 6,000 pounds.

Should a table of factors not be convenient, then the **equivalent evaporation** is determined as follows:

Rule.—Subtract the temperature of the feed water from the total heat of 1 pound of steam at the pressure of evaporation. Add 32 to the remainder and multiply the sum by the actual evaporation in pounds. Divide the product by 966.1.

Example.—A boiler generates 2,000 pounds of dry steam per hour at a gauge pressure of 120 pounds, the feed water temperature being 60 degrees, what is the equivalent evaporation?

Solution.—From the **steam table,** No. 14, we find the total heat corresponding to a gauge pressure of 120 pounds is 1.188.64 B. T. U. Applying above rule we find:

Equivalent evaporation =

$$\frac{2000 \times (1.188.6. - 60 + 32)}{966.1} = 2402.7 \text{ pounds.}$$

Boiler Horse Power Test.—The standard boiler horse power is obtained by dividing the equivalent evaporation as has been explained by 34½, which represents the unit of **one standard** boiler horse power, that being the number of pounds of water evaporated per horse power from and at 212 degrees.

It is therefore seen that **before** we can determine the

ower of a boiler, it is first necessary to ascertain **ivalent evaporation** of the boiler..

iciency Tests.—To find the efficiency of a boiler, the number of heat units usefully expended in ting the water by the number of heat units supy the fuel.

find the efficiency in per cent multiply the numheat units by 100.

ample.—A boiler trial shows a useful expendi- 120.386.451 B. T. U., and a total supply of 190.- B. T. U., what is the efficiency of the boiler

lution.—

$$\textbf{iciency} = \frac{100 \times 120.386.451}{190.841.350} = 63 \text{ per cent.}$$

ality of Steam.—By the quality of steam is meant **ount** or the per cent of the water pumped into a that is evaporated into **dry steam.** The amount steam furnished by boilers varies greatly Most ers when generating steam rapidly, furnish a cernount of wet steam, which is water remaining orated in the steam. As this water does no userk, in fact, is most objectionable, both on the s of safety and economy, it should be **deducted** e amount of evaporation of the boiler, or it would he boiler show a higher efficiency than it really ed.

lorimeter.—The apparatus used for the purpose rmining the amount of moisture contained in s called a **calorimeter,** the simplest form of which **Barrel Calorimeter.** Its operation is very simple, ing of first weighing a barrel holding about 400

Total Heat in Heat Units from Water at 32° F.	Heat Units in Liquid from 32° F.	Heat of Vaporization in Heat Units.	Density or Weight of 1 Cu. ft. in lbs.	Volume of 1 lb. in Cubic Feet.	Weight of 1 Cubic ft. of Water.	Factor of Equivalent Evaporation from and at 212° F.
1146.6	180.8	965.8	0.03760	26.60	59.76 (Formula) 59.64 (Observed)	1.0000
1154.9	208.4	946.5	0.06128	16.32	59.04	1.0086
1160.8	227.9	932.9	0.08439	11.85	58.50	1.0147
1165.5	243.2	922.3	0.1070	9.347	58.07	1.0196
1169.3	255.9	913.4	0.1292	7.736	57.69	1.0235
1172.6	266.9	905.7	0.1512	6.612	57.32	1.0269
1174.2	271.9	902.3	0.1621	6.169	57.22	1.0286
1175.6	276.6	899.0	0.1729	5.784	57.08	1.0300
1176.9	281.1	895.8	0.1837	5.443	56.95	1.0314
1178.2	285.6	892.7	0.1945	5.142	56.82	1.0327
1179.5	289.8	889.8	0.2052	4.873	56.69	1.0341
1180.6	293.8	886.9	0.2159	4.633	56.59	1.0352
1181.8	297.7	884.2	0.2265	4.415	56.47	1.0365
1182.8	301.5	881.5	0.2371	4.218	56.36	1.0375
1183.9	305.0	879.0	0.2477	4.037	56.25	1.0386
1184.9	308.5	876.5	0.2583	3.872	56.18	1.0397
1185.9	311.8	874.1	0.2689	3.720	56.07	1.0407
1186.8	315.0	871.8	0.2794	3.580	55.97	1.0417
1187.7	318.2	869.6	0.2898	3.452	55.87	1.0426
1188.6	321.2	867.4	0.3003	3.330	55.77	1.0435
1189.5	324.2	865.3	0.3107	3.219	55.69	1.0444
1190.3	327.0	863.3	0.3212	3.113	55.58	1.0452
1191.1	329.8	861.3	0.3315	3.017	55.52	1.0461
1191.9	332.5	859.4	0.3420	2.924	55.44	1.0469
1192.8	335.2	857.5	0.3524	2.838	55.36	1.0478
1193.5	337.8	855.7	0.3629	2.756	55.29	1.0486
1194.3	340.3	853.9	0.3731	2.681	55.22	1.0494
1195.0	342.8	852.1	0.3835	2.608	55.15	1.0500
1195.7	345.2	850.4	0.3939	2.539	55.07	1.0508
1196.3	347.6	848.7	0.4043	2.474	54.99	1.0514
1197.0	349.9	847.1	0.4147	2.412	54.93	1.0522
1197.7	352.2	845.4	0.4251	2.353	54.86	1.0529
1198.3	354.4	843.9	0.4353	2.297	54.79	1.0535
1199.0	356.6	842.3	0.4455	2.244	54.73	1.0542
1199.6	358.8	840.8	0.4559	2.193	54.66	1.0549
1200.2	360.9	839.2	0.4663	2.145	54.60	1.0555
1203.1	370.9	832.2	0.5179	1.930	54.27	1.0585
1205.8	380.1	825.7	0.5699	1.755	54.03	1.0613
1208.3	388.5	819.8	0.621	1.609	53.77	1.0639
1210.6	396.5	814.1	0.674	1.488	53.54	1.0666

Table of the Properties of Saturated Steam.

Table No. 14.

pounds of water on a platform scale, the temperature the water being registered by a thermometer inserted the side of the barrel.

The steam from the boiler to be tested is then d charged into this barrel, through a hose or pipe ur the temperature of the water in the barrel reaches ab 140 degrees. The steam is then turned off and the b rel and its contents again weighed. The **difference** tween the weights, is the weight of the steam discharg into the water.

If **dry steam** is discharged into the water, it sho raise the temperature of the water in the barrel a c tain known amount. If the temperature does **not** ra that much, it then must be due to the steam not bei dry, but containing moisture.

From the steam table the temperature of the ste can be found, from which can be determined the amo of moisture in same, which gives the quality of steam.

Analysis of Coal.—The calorific value of fuels only be determined by a careful **chemical analysis,** wh requires a skilled chemist. Such an analysis sho show the moisture, the volatile matter, the carbon a ash in same.

Moisture.—This is found by first weighing a sm sample of the coal or fuel in a porcelain or platin crucible, and then heating same in a drying oven to temperature of about 225 degrees Fahrenheit. Th weigh the sample again, and the **loss** of weight rep sents the moisture.

Volatile Matter.—This is determined by weighi out a small portion of the undried pulverized sample i a platinum crucible and **covering tightly.** Heat it fo few minutes over a Bunsen burner, keeping up a bri

Temperature Fahr.	Heat Units per lb.	Weight, lbs. per cubic foot.	Temperature Fahr.	Heat Units per lb.	Weight, lbs. per cubic foot.	Temperature Fahr.	Heat Units per lb.	Weight, lbs. per cubic foot.	Temperature Fahr.	Heat Units per lb.	Weight, lbs. per cubic foot.
32°	0.00	62.42	110°	78.00	61.89	145°	113.26	61.28	179°	147.54	60.57
35	3.02	62.42	112	80.00	61.86	146	114.27	61.26	180	148.54	60.55
40	8.06	62.42	113	81.01	61.84	147	115.28	61.24	181	149.55	60.53
45	13.08	62.42	114	82.02	61.83	148	116.29	61.22	182	150.56	60.50
50	18.10	62.41	115	83.02	61.82	149	117.30	61.20	183	151.57	60.48
52	20.11	62.40	116	84.03	61.80	150	118.30	61.18	184	152.58	60.46
54	22.11	62.40	117	85.04	61.78	151	119.31	61.16	185	153.58	60.44
56	24.11	62.39	118	86.05	61.77	152	120.32	61.14	186	154.59	60.41
58	26.12	62.38	119	87.06	61.75	153	121.33	61.12	187	155.60	60.39
60	28.12	62.37	120	88.06	61.74	154	122.34	61.10	188	156.61	60.37
62	30.12	62.36	121	89.07	61.72	155	123.34	61.08	189	157.62	60.34
64	32.12	62.35	122	90.08	61.70	156	124.35	61.06	190	158.62	60.32
66	34.12	62.34	123	91.09	61.68	157	125.36	61.04	191	159.63	60.29
68	36.12	62.33	124	92.10	61.67	158	126.37	61.02	192	160.63	60.27
70	38.11	62.31	125	93.10	61.65	159	127.38	61.00	193	161.64	60.25
72	40.11	62.30	126	94.11	61.63	160	128.38	60.98	194	162.65	60.22
74	42.11	62.28	127	95.12	61.61	161	129.39	60.96	195	163.66	60.20
76	44.11	62.27	128	96.13	61.60	162	130.40	60.94	196	164.66	60.17
78	46.10	62.25	129	97.14	61.58	163	131.41	60.92	197	165.07	60.15
80	48.09	62.23	130	98.14	61.56	164	132.42	60.90	198	166.68	60.12
82	50.08	62.21	131	99.15	61.54	165	133.42	60.87	199	167.69	60.10
84	52.07	62.19	132	100.16	61.52	166	134.43	60.85	200	168.70	60.07
86	54.06	62.17	133	101.17	61.51	167	135.44	60.83	201	169.70	60.05
88	56.05	62.15	134	102.18	61.49	168	136.45	60.81	202	170.71	60.02
90	58.04	62.13	135	103.18	61.47	169	137.46	60.79	203	171.72	60.00
92	60.03	62.11	136	104.19	61.45	170	138.46	60.77	204	172.73	59.97
94	62.02	62.09	137	105.20	61.43	171	139.47	60.75	205	173.74	59.95
96	64.01	62.07	138	106.21	61.41	172	140.48	60.73	206	174.74	59.92
98	66.01	62.05	139	107.22	61.39	173	141.49	60.70	207	175.75	59.89
100	68.01	62.02	140	108.22	61.37	174	142.50	60.68	208	176.76	59.87
102	70.00	62.00	141	109.23	61.36	175	143.50	60.66	209	177.77	59.84
104	72.00	61.97	142	110.24	61.34	176	144.51	60.64	210	178.78	59.82
106	74.00	61.95	143	111.25	61.32	177	145.52	60.62	211	179.78	59.79
108	76.00	61.92	144	112.26	61.30	178	146.53	60.59	212	180.79	59.76

B. T. U. in a Pound of Water at Different Temperatures.
Table No. 15.

red heat and then heat without cooling over a blast furnace for the same length of time at a white heat. Allow the sample to cool and weigh it. The loss in weight represents the loss of the hydrocarbons and the moisture, these being known as the **volatile matter.**

Fixed Carbon.—Place what is left of the sample after having determined the volatile matter as above explained, into a crucible and weigh it. Then heat it over a Bunson burner, holding the crucible, which is open to the air, in such a position that it will be exposed to the direct heat or flame of the burner. In this way all the carbon will be burned off, leaving only the **ash.** Now weigh the crucible and the **difference** in the weights is the amount of **fixed carbon** which was originally in the sample. The crucible should be heated in this way several times and weighed each time in order to be certain that all the carbon has been burned out of the sample.

Ash.—To ascertain the amount of ash, either subtract the weight of the crucible from the combined weight of it and the ash, or weigh the ash directly on the scales.

Comparative Value of Fuels.—Table No. 12 shows the value for steam making of American coals from and at 212 degrees Fahrenheit:

Petroleum.—Crude oil, fuel oil, or any distillate:

Per cent of ash, .o.

Heat units per pound, 20.746.

Pounds of water evaporation, 21.47.

Per cent incombustible matter, 25.

Heat units available for steam-making, 10.920.

Horse power per pound, 4.238.

Evaporation per pound from and at 212 degrees Fahrenheit, 11.25.

mparative Cost.—To estimate the **cost** o
red with other fuels, the following table
it units in each of the most common fuels,
the **cost** can be readily figured, taking as a
nber of heat units in one gallon of oil as 151,000
U.

	Heat Units per 1,000 cubic feet.
Gas	1,000,000
(Gas Machine), 20 can .	815,500
lluminating Gas, averag	650,000
Gas (from Bituminous	377,000
nd Producer Gas, mixed........	175,000
r Gas	150,000

h oil at 4 cents a gallon, the cost of equivalent uld be as follows:

		Per 1,000 cubic feet.
Gas	at	.264
, 20 candle power................	at	.216
Illuminating Gas, average........	at	.172
Gas (from Bituminous Coal)......	at	.099
and Producer Gas, mixed.........	at	.046
r Gas	at	.039

minating Gas.—

		Per 1,000 cubic feet.
l at 7 cents, would equal gas.....	at	.301
il at 8 cents, would equal gas.....	at	.340
il at 9 cents, would equal gas.....	at	.387
il at 10 cents, would equal gas.....	at	.430
il at 11 cents, would equal gas.....	at	.473
il at 12 cents, would equal gas.....	at	.516

Natural Gas.—

	Per 1,000 cubic
With oil at 5 cents, would equal gas.....at	.330
With oil at 6 cents, would equal gas.....at	.397
With oil at 7 cents, would equal gas.....at	.463
With oil at 8 cents, would equal gas.....at	.529

Wood.—Perfectly dry wood contains about 50 cent carbon, and for steam raising purposes about 2 pounds of dry wood are equal to 1 pound average qua of soft coal. Wood is usually classified as hard or s

Hard woods include oak, maple, hickory, birch, nut and beech.

Soft woods consist of pine, fir, spruce, elm, chest poplar and willow.

It has been found that hard wood gives less per pound than soft wood.

Calorific Values of Woods.—The relative calo value of different woods as compared with coal is as lows, viz.:

Cord of Wood.—	Value in lbs. of Coal.
Hickory, shell bark..............	1910
Oak, chestnut	1690
Oak, white	1670
Ash, white	1440
Dogwood	1560
Oak, black	1390
Oak, red	1390
Beech, white	1380
Maple, hard (sugar).............	1230
Maple, soft	1140
Cedar, red	1080
Magnolia	1160
Pine, yellow	1060
Sycamore	1020

Butternut	1090
Pine, New Jersey	916
Pine, pitch	812
Pine, white	800
Poplar, Lombardy	761
Chestnut	1000
Poplar, yellow	1080

Values in British Thermal Units Per Pound.—The value of different kinds of wood in B. T. U. per pound, on a basis of 1 pound of coal equals 2 1/3 pounds of dry wood, is as follows:

Name.	B. T. U.
Oak	8316
Ash	8480
Elm	8510
Beech	8591
Birch	8586
Fir	9063
Pine	9153
Poplar	7834
Willow	7926

Refuse.—This includes refuse, garbage and all character of municipal waste. Below is given the results of official tests made in several English cities of the fuel value of refuse, the evaporation being taken from and at 212 degrees Fahrenheit:

Accrington, 1.39 pounds.
Beckenhowe, 1.512 pounds.
Blackburn, 1.297 pounds.
Bolton, 0.8 pounds.
Bradford, 0.882 pounds.
Bury, 1.58 pounds.
Colme, 1.00 pounds.

RULES FOR CONDUCTING BOILER TRIALS.

Adopted by the American Society of Mechanical Engineers.

Code of 1898. (Abridged.)

I. **Determine at the outset** the specific object of the proposed trial, whether it be to ascertain the capacity of the boiler, its efficiency as a steam generator, its efficiency and its defects under usual working conditions, the economy of some particular kind of fuel, or the effect of changes of design, proportion, or operation; and prepare for the trial accordingly.

II. **Examine the boiler,** both outside and inside; ascertain the dimensions of grates, heating surfaces, and all important parts; and make a full record, describing the same, and illustrating special features by sketches. The area of heating surface is to be computed from the outside diameter of water tubes and the inside diameter of fire tubes.

III. **Notice the general condition** of the boiler and its equipment, and record such facts in relation thereto as bear upon the objects in view.

IV. **Determine the character of the coal** to be used. For tests of the efficiency or capacity of the boiler for comparison with other boilers, the coal should, if possible, be of some kind which is commercially regarded as a standard.

For New England and that portion of the country east of the Allegheny mountains, good anthracite egg coal, containing not over 10 per cent of ash, and semi-bituminous Clearfield (Pa.), Cumberland (Md.), and Pocahontas (Va.) coals are thus regarded. West of the Allegheny mountains, Pocahontas (Va.) and New River (W. Va.) semi-bituminous, and Youghiogheny or Pitts-

burg bituminous coals are recognized as standards. There is no special grade of coal mined in the Western States which is widely recognized as of superior quality or considered as a standard coal for boiler testing. Big Muddy lump, an Illinois coal mined in Jackson County, Ill., is suggested as being of sufficiently high grade to answer the requirements in districts where it is more conveniently obtainable than the other coals mentioned above.

V. **Establish the correctness of all apparatus** used in the test for weighing and measuring. These are:

1. Scales for weighing coal, ashes, and water.

2. Tanks, or water meters for measuring water. Water meters, as a rule, should only be used as a check on other measurements. For accurate work, the water should be weighed or measured in a tank.

3. Thermometers and pyrometers for taking temperatures of air, steam, feed water, waste gases, etc.

4. Pressure gauges, draught gauges, etc.

The kind and location of the various pieces of testing apparatus must be left to the judgment of the person conducting the test; always keeping in mind the main object, i. e., to obtain authentic data.

VI. See that the boiler is thoroughly heated to its usual working temperature before the trial. If the boiler is new and of a form provided with a brick setting, it should be in regular use at least a week before the trial, so as to dry and heat the walls. If it has been laid off and becomes cold, it should be worked before the trial until the walls are well heated.

VII. The boiler and connections should be proved to be free from leaks before beginning a test, and all water connections, including blow and extra feed pipes, should be disconnected, stopped with blank flanges, or

in the boiler room, of the temperature of the furnace when a furnace pyrometer is used, also of the pressure of steam, and of the reading of the instruments for determining the moisture in the steam. A log should be kept on properly prepared blanks containing columns for record of the various observations.

XIV. Quality of Steam.—The percentage of moisture in steam should be determined by the use of either a throttling or a separating steam calorimeter. The sampling nozzle should be placed in the vertical steam pipe rising from the boiler. It should be made of ½-inch pipe, and should extend across the diameter of the steam pipe to within half an inch of the opposite side, being closed at the end and perforated with not less than twenty ½-inch holes equally distributed along and around its cylindrical surface, but none of these holes should be nearer than ½-inch to the inner side of the steam pipe. The calorimeter and the pipe leading to it should be well covered with felting. Whenever the indications of the throttling or separating calorimeter show that the percentage of moisture is irregular, or occasionally in excess of 3 per cent, the results should be checked by a steam separator placed in the steam pipe as close to the boiler as convenient, with a calorimeter in the steam pipe just beyond the outlet from the separator. The drip from the separator should be caught and weighed, and the percentage of moisture computed therefrom added to that shown by the calorimeter.

Superheating should be determined by means of a thermometer placed in a mercury-well inserted in the steam pipe. The degree of superheating should be taken as the difference between the reading of the thermometer for superheated steam and the readings of the

same thermometer of saturated steam at the same pressure as determined by a special experiment, and not by reference to steam tables.

XV. Sampling the Coal and Determining Its Moisture.—As each barrow load or fresh portion of coal is taken from the coal pile, a representative shovelful is selected from it and placed in a barrel or box in a cool place and kept until the end of the trial. The samples are then mixed and broken into pieces not exceeding 1 inch in diameter, and reduced by the processes of repeated quartering and crushing until a final sample weighing about 5 pounds is obtained, and the size of the larger piece is such that they will pass through a sieve with ¼-inch meshes. From this sample two one-quart, air-tight glass preserving jars, or other air-tight vessels which will prevent the escape of moisture from the sample, are to be promptly filled, and these samples are to be kept for subsequent determinations of moisture and of heating value and for chemical analyses. During the process of quartering, when the sample has been reduced to about 100 pounds, a quarter to a half of it may be taken for an approximate determination of moisture. This may be made by placing it in a shallow iron pan, not over 3 inches deep, carefully weighing it, and setting the pan in the hottest place that can be found on the brickwork of the boiler setting or flues, keeping it there for at least 12 hours, and then weighing it. The determination of moisture thus made is believed to be approximately accurate for anthracite and semi-bituminous coals, and also for Pittsburg or Youghiogheny coal; but it cannot be relied upon for coals mined west of Pittsburg, or for other coals containing inherent moisture. For these latter coals it is important that a more accurate method be adopted. The method recom-

mended by the committee for all accurate tests, whatever the character of the coal, is described as follows:

Take one of the samples contained in the glass jars. and subject it to a thorough air-drying, by spreading it in a thin layer and exposing it for several hours to the atmosphere of a warm room, weighing it before and after, thereby determining the quantity of surface moisture it contains. Then crush the whole of it by running it through an ordinary coffee mill adjusted so as to produce somewhat coarse grains (less than 1/16 inch), thoroughly mix the crushed sample, select from it a portion of from 10 to 50 grams, weigh it in a balance which will easily show a variation as small as 1 part in 1,000, and dry it in an air or sand bath at a temperature between 240 and 280 degrees Fahrenheit for 1 hour. Weigh it and record the loss, then heat and weigh it again repeatedly, at intervals of an hour or less, until the minimum weight has been reached and the weight begins to increase by oxidation of a portion of the coal. The difference between the original and the minimum weight is taken as the moisture in the air-dried coal. This moisture test should preferably be made on duplicate samples, and the results should agree within 0.3 to 0.4 of 1 per cent, the mean of the two determinations being taken as the correct result. The sum of the percentage of moisture thus found and the percentage of surface moisture previously determined is the total moisture.

XVI. Treatment of Ashes and Refuse.—The ashes and refuse are to be weighed in a dry state. If it is found desirable to show the principal characteristics of the ash, a sample should be subjected to a proximate analysis and the actual amount of incombustible material determined. For elaborate trials a complete analysis of the ash and refuse should be made.

ıustion is to burn the sample of coal in an atmos-
f oxygen gas, the coal to be sampled as directed
:le XV of this code.

e chemical analysis of the coal should be made
· an expert chemist. The total heat of combus-
nputed from the results of the ultimate analysis
obtained by the use of Dulong's formula.

is desirable that a proximate analysis should be
thereby determining the relative proportions of
matter and fixed carbon. These proportions
an indication of the leading characteristics of
l, and serve to fix the class to which it belongs.
additional indication of the characteristics of the
ie specific gravity should be determined.

/III. **Analysis of Flue Gases.**—The analysis of
: gases is an especially valuable method of deter-
the relative value of different methods of firing,
different kinds of furnaces. In making these
s great care should be taken to procure average
s—since the composition is apt to vary at dif-
points of the flue. The composition is also apt

ment may be employed which shows the weight of th sample of gas passing through it.

XIX. Smoke Observations.—It is desirable to hav a uniform system of determining and recording th quantity of smoke produced where bituminous coal i used. The system commonly employed is to expres the degree of smokiness by means of percentages de pendent upon the judgment of the observer. The com mitte does not place much value upon a percentag method, because it depends so largely upon the person element, but if this method is used, it is desirable tha so far as possible, a definition be given in explicit term as to the basis and method employed in arriving at th percentage. The actual measurement of a sample soot and smoke by some form of meter is to be pr ferred.

XX. Miscellaneous.—In tests for purposes scientific research, in which the determination of all t variable entering into the test is desired, certain obse vations should be made which are in general unnece sary for ordinary tests. These are the measurement the air supply, the determination of its contained mois ure, the determination of the amount of heat lost radiation, of the amount of infiltration of air throug the setting, and (by condensation of all the steam ma by the boiler) of the total heat imparted to the wate

As these determinations are rarely undertaken, is not deemed advisable to give directions for mak them.

XXI. Calculations of Efficiency.—Two method

defining and calculating the efficiency of a boiler are recommended. They are:

1. Efficiency of the boiler

$$= \frac{\text{Heat absorbed per lb. combustible}}{\text{Calorific value of 1 lb. combustible}}$$

2. Efficiency of the boiler and grate

$$= \frac{\text{Heat absorbed per lb. coal}}{\text{Calorific value of 1 lb. coal}}$$

The first of these is sometimes called the efficiency based on combustible, and the second efficiency based on coal. The first is recommended as a standard of comparison for all tests, and this is the one which is understood to be referred to when the word "efficiency" alone is used without qualification. The second, however, should be included in a report of a test, together with the first, whenever the object of the test is to determine the efficiency of the boiler and furnace together with the grate (or mechanical stoker), or to compare different furnaces, grates, fuels, or methods of firing.

The heat absorbed per pound of combustible (or per pound of coal) is to be calculated by multiplying the equivalent evaporation from and at 212 degrees per pound combustible (or coal) by 965.7.

XXII. The Heat Balance.—An approximate "heat balance," or statement of the distribution of the heating value of the coal among the several items of heat utilized and heat lost may be included in the report of a test when analyses of the fuel and of the chimney gases have been made. The methods of computing the heat balance and the form in which it should be reported, are given in Steam Boiler Efficiency.

XXIII. Report of the Trial.—The data and results

should be reported in the manner given in eithe the two following tables, omitting lines where t have not been made as elaborate as provided for tables. Additional lines may be added for data to the specific object of the test. The extra lines be classified under the headings provided in the and numbered as per preceding line, with sub-le b, etc. The short form of report is recommen commercial tests, and as a convenient form of ab the longer form for publication when saving of s desirable. For elaborate trials, it is recommend the full log of the trial be shown graphically, by of a chart.

TABLE OF DATA AND RESULTS OF ORATIVE TEST,

Arranged in Accordance With the Short Form by the Boiler Test Committee of the Ame Society of Mechanical Engineers.

Made by..........on..........boiler, at......
determine ....
Grate surface ....
Water-heating surface ....
Superheating surface ....
Kind of fuel............................
Kind of furnace.........................

Total Quantities.

1. Date of trial........................
2. Duration of trial....................
3. Weight of coal as fired..............
4. Percentage of moisture in coal....... p
5. Total weight of dry coal consumed...
6. Total ash and refuse................
7. Percentage of ash and refuse in dry coal p

tal weight of water fed to the boiler lbs.
ater actually evaporated, corrected for moisture or superheat in steam.. lbs.

Hourly Quantities.

ry coal consumed per hour......... lbs.
ry coal per hour per square foot of grate surface .... lbs.
Vater fed per hour.................. lbs.
quivalent water evaporated per hour from and at 212 degrees corrected for quality of steam............... lbs.
Equivalent water evaporated per square foot of water-heating surface per hour .... lbs.

Average Pressures, Temperatures, Etc.

Average boiler pressure.............lbs. per sq. in.
Average temperature of feed water... deg.
Average temperature of escaping gases deg.
Average force of draft between damper and boiler .... ins. of water.
Percentage of moisture in steam, or number of degrees of superheating.

Horse Power.

Horse power developed (Item 13 ÷ 34½) .... H. P.
Builders' rated horse power......... H. P.
Percentage of builders' rated horse power .... per cent.

Economic Results.

Water apparently evaporated per pound of coal under actual conditions. (Item 8 ÷ Item 3)......... lbs.
Equivalent water actually evaporated from and at 212 degrees per pound

[redacted]

of coal as fired. (Item 13 ÷(Item 5 ÷ 2)) ....

25. Equivalent evaporation from and at 212 degrees per pound of dry coal. (Item 13 ÷ Item 10)..............

26. Equivalent evaporation from and at 212 degrees per pound of combustible. [Item 13 ÷ [(Item 5 — Item 6) ÷ Item 2]......................

(If Items 23, 24 and 25 are not corrected for quality of steam, the fact should be stated.)

Efficiency.

27. Heating value of the coal per pound.. B.

28. Efficiency of boiler (based on combustible) ....

29. Efficiency of boiler, including grate (based on coal)..................

Cost of Evaporation.

30. Cost of coal per ton delivered in boiler room .... $

31. Cost of coal required for evaporation of 1,000 pounds of water from and at 212 degrees.................... $

Boiler, Horse-power	No. Tubes in Width	No. Tubes in Height	Length Tubes in Feet	Diam. of Drum, Inches	Length of Drum, Feet	Average Weight in Tons	Length of Setting, Feet	Width of Setting, Feet	Height of Setting, Feet	No. of Common Brick	No. of Fire Brick	Diam. of Safety Valve, In.	Heating Surface in Sq. Ft.	Area of Grate, Square Feet
10	3	4	6	24	10	3	9	4	8½	2200	590	2	119	5.21
12	3	4	8	24	12	3¼	11	4	8½	2620	740	2	150	6.25
15	3	5	8	24	12	3½	11	4	9	2760	790	2	181	7.28
20	3	5	10	24	15	4¼	13	4	9	3170	980	2	219	8.33
25	4	5	10	30	15	5	13	5	9½	3350	1000	2½	293	10.67
30	4	5	12	30	17	5¼	15	5	9½	3760	1170	2½	343	10.67
35	4	6	12	30	17	6	16	5½	11	5970	1510	3	401	12.00
40	4	6	14	30	19	6½	19	5½	11	7460	1680	3	460	13.33
45	4	7	14	30	19	7	19	5½	11	8630	1410	3½	526	13.33
50	4	8	14	30	19	7¼	19	5½	12	8920	1540	3½	593	13.33
65	5	8	14	36	19	8½	19	6	12½	9180	1600	3½	735	16.25
75	6	7	16	36	21	10	21	7	12	9890	1650	3½	870	19.17
85	6	8	16	36	21	11	21	7	12½	10500	1738	4	983	19.17
95	6	9	16	36	21	11½	21	7	13	10900	1950	4	1098	23.00
105	6	9	18	36	24	12	23	7	13½	12570	1970	5	1218	23.00
110	7	8	18	36	24	12¼	23	7½	13	12400	2000	5	1265	26.50
120	7	9	18	36	24	12½	23	7½	13½	12750	2010	5	1411	26.50
125	7	9	18	42	24	12¾	23	7½	14	12800	2160	5	1426	26.50
140	8	9	18	42	24	14	23	8	14	12820	2060	5	1619	30.00
150	12	7	16	36	21	18¼	21	10	12½	13160	2020	4	1741	36.67
160	9	9	18	48	24	16¾	23	8	14½	12960	2060	5	1827	33.50
175	12	8	16	36	21	18¾	21	10	13	13180	2160	4	1966	36.67
190	12	9	16	36	21	20¼	21	10	13½	13300	2200	4	2197	44.00
210	12	9	18	36	24	20¾	23	10	13½	13500	2230	5	2437	44.00
220	14	8	18	36	24	21¼	23	11½	13	13800	2310	5	2531	51.00
240	14	9	18	36	24	23¼	23	11½	13½	14000	2350	5	2823	51.00
250	14	9	18	42	24	24¼	23	11½	14	14000	3000	5	2852	51.00

Table No. 16.

Q. What is the operation of the one-pipe

A. In this system the steam from the boil ried to the risers through **one** pipe, the con flowing back through the **same** pipe.

Q. What is the operation of the **two-pipe**

A. This system has two connections for e ator, one serving as an inlet for the **steam** and as an outlet for the **water** of condensation, t passing through one pipe and the water flowin the boiler through the return pipe.

Q. What is the operation of the exhaust pressure system?

A. In this system the steam heating mai nected to the **exhaust pipe** from the engine or p also to a **live** steam pipe from the boiler. steam is only used when there is an **insufficien** haust steam. Should the supply of exhaust s come **excessive,** the excess will escape by the o the back pressure valve and its discharge into th phere.

Q. What is the operation of the vacuum s

A. In this system the returns are connec receiver which collects the air and water in the To this receiver is connected a **vacuum pum** removes all the air and water in the system, a tains a **vacuum** at any desired degree. When tem is used there is **no** back pressure on the en

Q. What are **hot water** heating systems?

A. Hot water systems are very similar to t systems, except that **hot water** flows through and radiators instead of steam.

Q. How is the temperature in a hot wate system regulated?

A. By varying the temperature of the water flowing through the pipes.

Q. What is meant by central station heating?

A. It is the heating of large districts from **one central plant**, instead of from separate plants in each building or dwelling.

Q. How is the heat transmitted from the central station?

A. Through pipes properly insulated, which are ually laid underground.

Q. What is meant by one **boiler horse power?**

A. It is the evaporation of 34.48 pounds of water om and at 212 degrees Fahrenheit, or the evaporation 30 pounds of water per hour from feed water having temperature of 100 degrees Fahrenheit into steam at pounds pressure. It is equal to the **absorption** of 33,330 B. T. U. by the water in the boiler.

Q. What is meant by the **efficiency** of a boiler?

A. It is the ratio between the heat units utilized in the production of steam, and the heat units contained in the fuel used.

Q. What is the equivalent evaporation?

A. It is the reduction to a **common basis** of the evaporation of different boilers operating under different conditions.

Q. What are factors of evaporation?

A. They are the numbers or factors representing the amount of dry steam under different pressures contained in every pound of feed water evaporated.

Q. How do you find the equivalent evaporation of any boiler?

A. Multiply the actual evaporation by the factor of evaporation.

Q. What is a calorimeter?

A. It is an apparatus used for the purpo: mining the amount of moisture contained in st

Q. What are the standard rules for boiler trials?

A. The rules adopted by the American Mechanical Engineers.

The following table, taken from experiments of Mr. Brill, indicates the savings due to various coverings, the cost of the covering and the cost of applying the same, at the time these experiments were made, viz. . 1895.

Kinds of Covering	Savings Due to Coverings				Cost to Apply 60 Feet of Covering	Cost of 60 Feet of Covering	Gross Saving in One Year Due to 60 Feet Covering
	Per Hour per Square Foot Pipe		Per 100 Square Feet per Year				
	B. T. U.	Pounds Steam	Pounds Steam	Dollars			
Magnesia	631.986	.7258	635801	110.82	$1.92	$31.95	$150.14
Rock wool	666.637	.7656	670666	116.90	2.02	27.60	158.38
Mineral wool	658.988	.7568	662957	115.55	2.34	21.00	156.55
Fire felt	599.730	.6888	603389	105.17	2.10	29.70	142.48
Manville sectional	641.295	.7365	645174	112.45	3.21	29.35	152.35
Manville sectional and hair felt	678.777	.7796	682930	119.03	5.96	34.60	161.26
Manville wool cement	642.601	.7380	646488	112.68	17.06	25.50	152.66
Champion mineral wool	650.277	.7468	654197	114.03	2.85	16.02	154.49
Hair felt	621.588	.7139	625376	109.00	3.00	10.50	147.67
Riley cement	477.022	.5479	479960	83.66	20.00	8.71	113.34
Fossil meal	497.274	.5711	500284	87.20	12.75	21.45	118.14

Pipe Covering.
Table No. 18.

CHAPTER XV.

THE STEAM ENGINE.

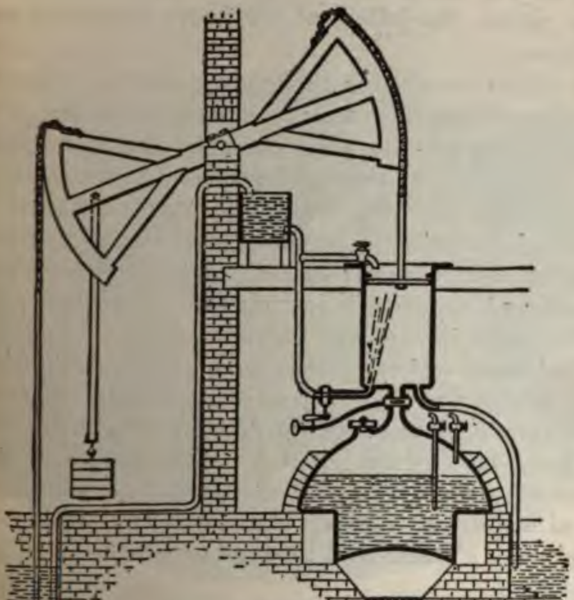
Definition.—The **Steam Engine** is an apparatus f converting heat into mechanical power.

The Savery Engine.—The first practical engine wa constructed by Thomas Savery in the year 1693, and wa used to pump water out of a mine, as were all the firs constructed engines. It consisted simply of two oval ves sels placed side by side and in communciation with boiler. The lower parts of the vessels were connecte by tubes fitted with suitable valves; steam from th boiler was admitted to one of the vessels, and then con densed by cooling the surface of the vessel with wate In this way a **vacuum** was formed inside the vesse which upon opening the valve, drew up the water fro the mine until the vessel was full. The valve was the closed and steam again admitted, so that upon openin the second valve the water was forced out through th discharge pipe. The two vessels were worked **alte nately,** so that while one was being filled, the other w open to the boiler and being emptied.

Defect.—The waste of steam in this apparatus w enormous, the consumption of coal being about **twen times** as great as required by a modern steam engi to do the same amount of work.

The Newcomen Engine.—In 1705 Newcomen great improved upon the Savery engine by reducing t amount of steam necessary to be condensed in operati the Savery engine, by making use of a **piston** whi worked in a **cylinder.**

In the Newcomen engine shown in Fig. 134 the was a horizontal lever or beam pivoted at the center, an carrying at one end a heavy rod which connected wit



Sectional View of the Newcomen Engine.
Fig. 134.

the pump in the mine below. A piston was hung from the other end of this lever, which piston worked up and down in a cylinder open at the top. Steam at atmospheric pressure was admitted from the boiler to this cylinder, and as the pressure was the same on **both** sides of the piston, the falling of the heavy pump rod **raised** the piston.

A jet of water was then introduced into the cylinder to condense the steam and form a vacuum. This left the piston with the pressure of the atmosphere, which is about 15 lbs. to the square inch, on one side of it, and but little pressure on the other, which difference in pressure forced the piston **down,** and in this way **raised** the pump rod. Steam was then again admitted into the cylinder and condensed, forcing the piston down again, and the pump in this way operated.

Cylinders.—The cylinders were usually made of **wood** and the workmanship so poor that a **tight** joint could not be made between the piston and the walls of the cylinder. This permitted the steam to escape from around the piston. To prevent this as much as possible, a jet of water was made to play on the top of the piston thus making a **water seal,** through which the steam could not escape.

One of the greatest troubles with all the first engines constructed was that they required some one to open and close the cocks to admit the steam and water, boys being usually employed for this work. In order to get time to play, one of them, rigged a catch at the end of a cord which was attached to the overhead beam, and in this way the first **automatic** engine was constructed. While the Newcomen engine was a great improvement on all previous efforts, it was also most wasteful and clumsy. Later, the cylinders were made of **iron**

wcomen Pumping Engine, Bardsley, Near Ashton-Under-Lyne.
Out of Use 1830.
From Mr. Henry Davey's paper before the Institution of
Mechanical Engineers.

instead of wood, but they were cast rough, and the workmanship far from perfect.

The James Watt Engine.—In the year 1764 James Watt, who was an instrument maker in Glasgow, Scotland, devised the present type of steam engine, and while the **workmanship** of the steam engine has been much improved since that day, no great improvement has been made upon his **ideas** and **suggestions,** with the one exception of **compound expansion.** All other improvements have been merely carrying out his ideas, which lack of good tools alone prevented him from executing.

Steam Engine Efficiency.—Watt found that to obtain the best results from a steam engine that it was necessary

"First, that the temperature of the cylinder should always be the same as that of the steam which entered it; and, secondly, that when the steam was condensed it should be cooled to as low a temperature as possible."

Separate Condenser.—Instead of condensing the steam **in** the cylinder itself, he used a **separate** vessel or **condenser** into which he injected the water to condense the steam. In this way he kept the cylinder almost as hot as the entering steam. He made the piston **tight** by using greater care in its construction, so that it was not necessary to keep it under a water seal, which seal greatly cooled the piston and the cylinder walls.

Closed Cylinder.—All his predecessors had left **one end** of the cylinder open, which permitted the steam to be used only on **one side** of the piston, but **Watt** closed **both** ends of the cylinder, thus not only preventing the air from cooling the piston, but permitted the steam to act on **both sides** of the piston, making the engine double **acting.**

In order to keep the cylinder as hot as the entering

team, he **jacketed** the cylinder; but what was far more mportant, he used the steam **expansively,** that is, the steam was shut off when the piston had made only **a part** of the stroke, permitting the **expansion** of the steam to complete the stroke, and thus adding greatly to the **economy** of the engine in the saving of steam, which would be otherwise wasted.

Classes of Engines.—Engines are classified according to the **work** for which they are built, as, (1) stationary, portable, etc.; (2) from the **arrangement** of the cylinders, as, simple, compound, triple expansion, etc.; (3) according to the character of the **valves** to control the distribution of the steam, as plain slide valve, automatic cut off, Corliss, etc.; (4) according to the **motion** of the piston, as reciprocating and rotary.

Subdivisions.—The principal subdivisions of these types of engines are (1) condensing engines, (2) non-ondensing engines, (3) single acting engines, (4) double acting engines.

Definition of Types.—A stationary steam engine an engine designed to remain in the **same place** where stalled, doing its work without changing its location.

Engines that operate factories, office buildings, electric light plants or any character of **stationary** steam plants, belong to this class.

A portable steam engine is an engine designed to be moved from place to place, or one that does its work while in transit.

Such engines as marine and locomotive engines are ble engines, they being designed to propel steam- or trains of cars from place to place. Also, hoist- gines, steam hammers, steam drills, and all pump- lowing and fire engines belong to this class of en-

gines, as they are capable of being moved with ease from place to place.

Simple Engine.—This is an engine in which the steam is used expansively in only one cylinder. Should the steam be used in **more** than one cylinder before being exhausted or discharged, the engine is then said to be a **multiple** expansion engine.

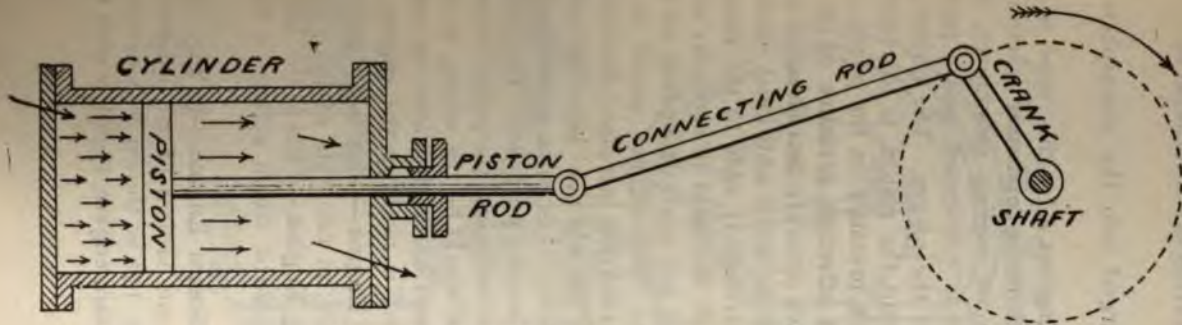
Compound Engine.—This is an engine which has **two** cylinders, the steam being expanded **twice** before its final discharge.

Triple Expansion Engine is one which has **three** cylinders, that is the steam is expanded **three** times before its discharge.

Reciprocating Steam Engine.—In this type of engine the work is done by the reciprocating motion of the piston, that is, its motion back and forth in the cylinder. This reciprocating motion of the piston must be changed into a continuous **rotary** motion before the power of the engine can be used. The form of mechanism used for this purpose is practically the same for all types of reciprocating engines. This reciprocating mechanism is shown in the diagram Fig. 135.

Rotary Engine.—In this type of engine the piston instead of **returning** to its starting point, continues turning in one direction, the piston and crank being connected to the shaft and rotating in the same chamber. In this type of engine the steam is not used expansive as is done in the reciprocating engine.

Non-Condensing Engine.—In this type of engine the steam after having been expanded in the cylinder down to the atmospheric pressure, or near that pressure



The Reciprocating Mechanism of an Engine.
Fig. 135.

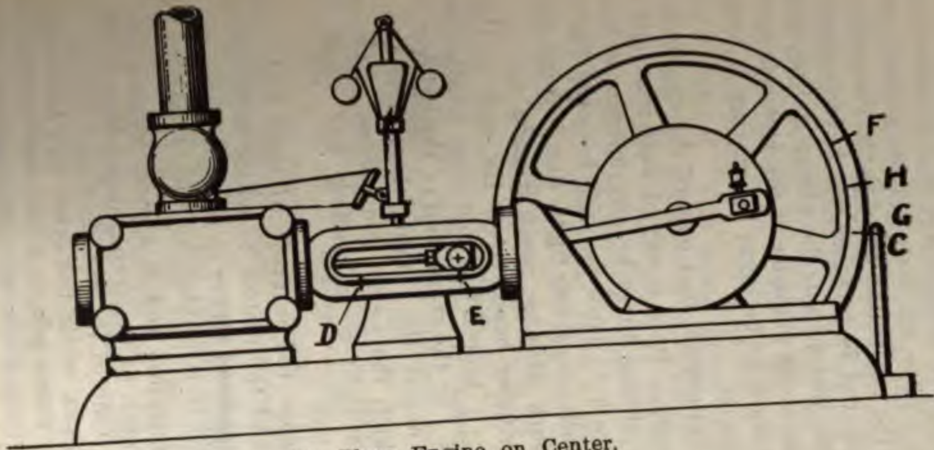
possible, is discharged into the atmosphere, or into a heating system.

Condensing Engines.—In this type of engine the steam is discharged into a **condenser** where it is brought in contact with some cooling substances, usually cold water, by which it is condensed, and a partial **vacuum** is produced behind the piston. The object of condensing the steam behind the piston, is to remove as much as possible the **back pressure** on the piston, and to thus **increase** the **mean effective pressure** on it throughout its stroke. The back pressure **decreases** the power of the engine it being just so much additional work for the engine to do, and therefore it adds to the **economy** of the engine to remove it, this gain in economy amounting to as much as 20 to 25 per cent, depending on the size and type of the engine. All engines would be made condensing were it not for the increased first cost of the engine, together with the additionl labor and attention necessary. Also, at times it is more economical to use the exhaust steam for heating purposes. The cost of the necessary water for condensing purposes is also in many places greater than would be the saving in fuel, as it requires about 25 times as much water for condensing, as for the steam which is used by the engine.

Single Acting Engine.—This is an engine in which the steam acts only on one side of the piston.

Double Acting Engine.—This is the form of engine now generally used, the steam acting on **both** sides of the piston.

Parts of the Steam Engine.—In Fig. 147, is shown the reciprocating mechanism of an ordinary steam engine, while in Fig. 137 is shown in elevation the usual type of a **simple steam engine,** together with the principal parts.



To Place Engine on Center.
Fig. 136.

Reciprocating Parts.—These are all the parts which move back and forth, either in a horizontal or a vertical direction. They are viz.: (1) the piston; (2) the piston rod; (3) the cross head and (4) the connecting rod. The connecting rod is attached to the crosshead, the crosshead to the piston rod, the piston rod to the piston, and on the piston the **pressure** of the steam is exerted to perform the work to be done by moving it back and forth in the cylinder.

The Cylinder is that part of the engine in which the piston moves. It is made of **cast iron** and accurately bored, for should there be any uneveness it would permit the steam to pass through between the piston and cylinder walls, or, if **too tight,** it will cause the piston to stick, or work with too much **friction.**

The **cylinder heads** cover the ends of the cylinder, being securely bolted thereon, thus making the cylinder steam tight. In the **crank end** of the cylinder head, that is the end nearer the crank, there is left an **opening** through which the piston rod passes. This opening is made steam tight by a **stuffing box** which surrounds the piston rod.

The **piston rod** is made of steel and connects the cross-head and the piston, to which it is rigidly fixed.

The **cross-head** serves to **join** the piston rod and connecting rod. It is guided by the cross-head **guides.**

The **connecting rod** is a steel forging from 3 to 8 times the length of the crank, depending on the type of the engine. One of its ends is joined to the cross-head by the **wrist-pin,** while the other end is fastened to the crank by the **crank pin,** and this end revolves with the crank in a circle while the other end slides back and forth with the cross-head, and in this way is changed the **reciprocating** motion of the piston, into the **circular** motion of the crank and fly wheel.

The **crank pin** forms the connection between the crank and the connecting rod.

The **crank,** which is equal in length to **one-half** the stroke of the piston or engine, converts the reciprocating motion of the connecting rod into a circular motion as above explained. The crank may be simply an **arm,** or a complete **disc,** keyed to one end of the shaft as shown in the above Figs. 135 and 137.

The **shaft** transmits the rotary motion from the crank to the fly wheel. The **steam chest** receives the steam directly from the **boiler,** before it passes through the steam ports to the cylinder. The **eccentric** is a disc, keyed to the shaft so that its center and the center of the shaft do not coincide. It is a species of a crank, its peculiarity being that its crank pin is increased to such a size that it **exceeds** the diameter of the shaft.

The distance between the center of the crank pin and the center of the shaft, is called the **radius of eccentricity.**. The radius therefore is the distance between the center of the disc and the center of the shaft.

Eccentric.—In Fig. 141 is shown a diagram of an eccentric, the parts of which are as follows: (1) shaft center; (2) eccentric center; (0) radius of eccentric, (4) eccentric strap; (5) set bolts; (6) eccentric rod; (7) eccentric rod foot.

The distance 8 is called the **throw** of the eccentric, and is twice the radius, or the difference between the heavy and light sides of the eccentric. The eccentric is therefore equivalent to a **crank** whose length is equal to the radius of the eccentric.

The Engine Base.—This must be massive enough to absorb the vibrations of the moving parts, thus reducing the wear on all the parts of the engine as much as possible. It also serves as a top plate to the masonry,

permitting the engine to be set and aligned with accuracy.

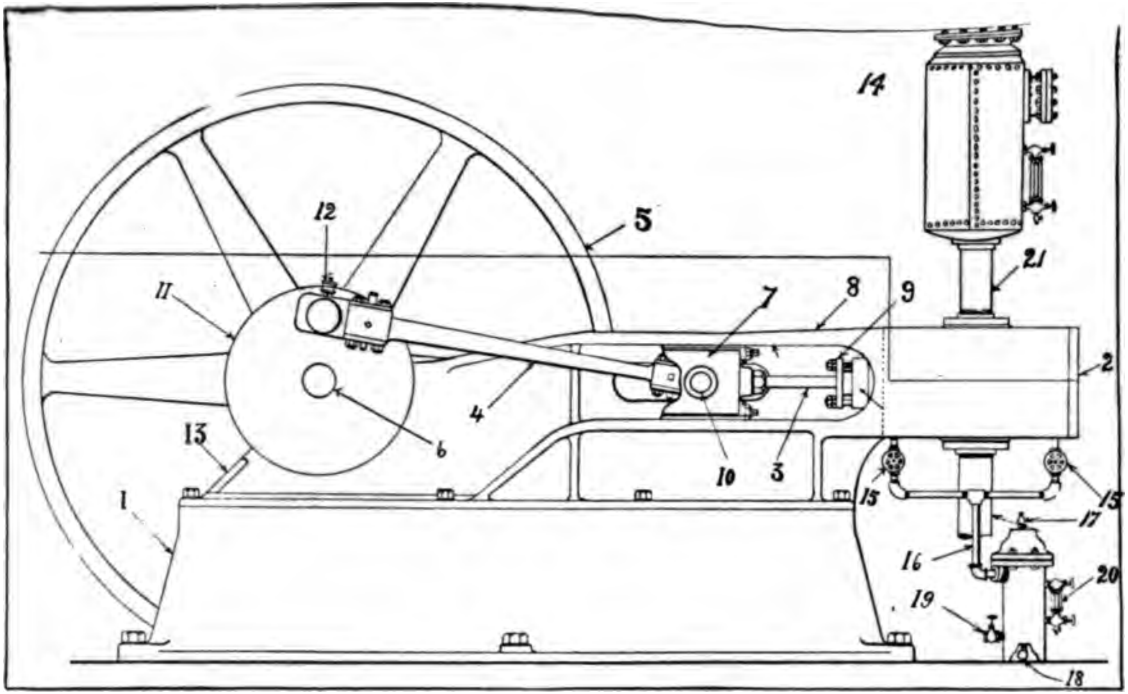
The **Tangee** or **Porter-Allen** type of engine frame has only **one** main bearing for the crank shaft, and is most commonly used for high speed engines.

In the **Girder** type of engine frame, the crank end and cylinder end are supported on **separate** foundations, the middle part between the supports carrying the cross-head slides.

All the principal parts of an ordinary steam engine are shown in Fig. 137 and148, and they must be **thoroughly** understood and remembered in order to understand the **operation** of the steam engine.

In Fig. 137 is shown the side elevation of a high speed horizontal engine, with steam separator and trap, in which the principal parts are as follows, the numbers corresponding to those shown in this illustration, **viz.**:

1. Engine frame.
2. Cylinder head.
3. Piston rod.
4. Connecting rod.
5. Belt or fly wheel.
6. Shaft.
7. Crosshead.
8. Engine frame.
9. Stuffing box gland.
10. Wrist pin.
11. Crank wheel.
12. Crank pin oil cup.
13. Engine frame.
14. Steam separator.
15. Cylinder cocks.
16. Drain pipe.



The Parts of a Simple Engine, Showing Separator and Trap.
Fig. 137.

17. Vent cock of trap.
18. Discharge of trap.
19. Blow off valve of trap.
20. Water glass for trap.
21. Steam inlet pipe to engine.

In Fig. 145 is shown a sectional view of the pi with parts of the connecting rod and piston rod, bered as follows:

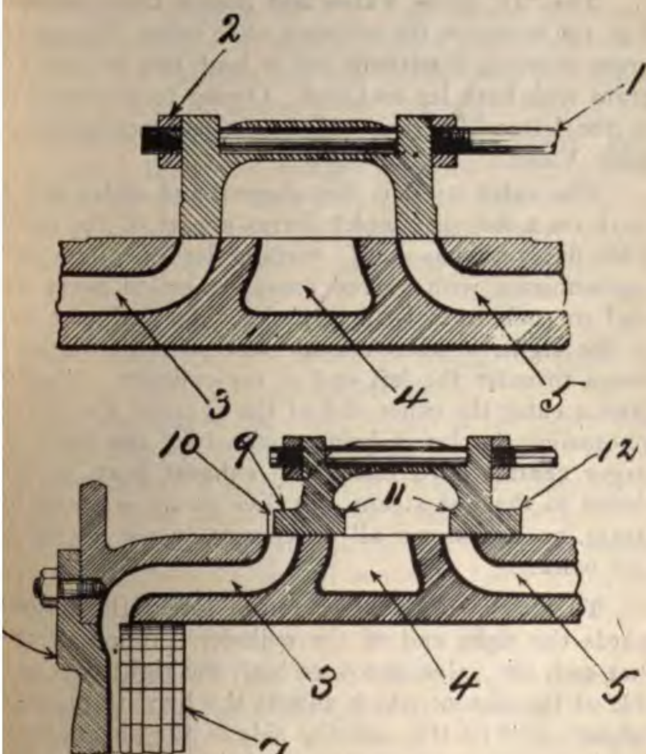
2. Section of piston.
3. Recesses for piston rings.
4. Section of piston.
5. Strap for crosshead brasses.
6. Wrist pin brasses.
7. Connecting rod.
8. Strap bolts crank end.
9. Key for adjusting crank pin brasses.
10. Crank pin brasses.
11. Strap for crank pin brasses.

Valves and Valve Gears.—In most engines the s distributing valves receive their motion from on more eccentrics and to have a perfect understandin any character of engine, the **first essential** is to ha thorough understanding of the **valves** and **valve gea** which is meant the distributing valves, the eccentric eccentric strap, the eccentric rod, the rocker and valve stem. Engines are usually constructed either a single valve, or with four valves.

Single Valve Engine.—In this type of engine, a **gle** valve controls the admission and distribution of steam for both ends of the cylinder, as in the com slide valve engine.

Four Valve Engine.—Such an engine has **sep** valves for the admission of the steam to the cylinder,

Sectional View of Ordinary Slide Valve.
Fig. 138.



...tion of Ordinary Slide Valve, With and Without Lap and Lead.
Fig. 139.

for its discharge or exhaust, as a Corliss engine. These valves are placed at each end of the cylinder.

Common Slide Valve Engine.—The **simplest** valve gear is that of the slide valve type, which is usually operated with one eccentric which is fastened to the shaft of the engine.

The "D" Slide Valve and Steam Distribution.—In Fig. 139 is shown the ordinary slide valve, the upper diagram showing it **without** lap or lead, and the lower diagram with **both** lap and lead. Owing to its resemblance to the letter "D," this valve is usually called the "D" Slide Valve.

The valve itself is box-shaped, and slides back and forth on a flat seat which forms a part of the cylinder. This flat seat has long rectangular openings which communicate with curved passages, called **ports,** which lead to each end of the cylinder. As the valve moves to the **right,** it uncovers the **left** port, permitting the steam to enter the **left** end of the cylinder. The steam cannot enter the other end of the cylinder for that port, or opening, is closed, being covered by the valve. The larger **central** port, called the **exhaust** port, is always closed to the **live** steam. By live steam is meant **fresh** steam, as it posseses all its energy, it not having done any work.

The steam pressure therefore forces the piston towards the **right** end of the cylinder. When it reaches that end, the valve uncovers both the right port on one side of the piston, which admits the live steam, and the **exhaust** port on the opposite side of the piston, through which is discharged or exhausted the now useless steam, the piston being again forced to the left end of cylinder. In order to open the exhaust port, so that the pressure on the opposite side of the piston will be at once re-

moved, the valve at its middle is made hollow, and by bringing at the same time the hollow part of the valve over the **middle** port and over the end port towards which the piston is moving, these two ports are put in communication with each other, permitting the steam behind the piston to escape, or be exhausted as it is called.

The upper diagram of Fig. 139 shows the valve in its **central** position, in which position steam is neither admitted to the cylinder nor exhausted from it. Numbers 3 and 5 are the steam ports through which steam is **admitted** into the cylinder. 4 is the exhaust port through which the steam **escapes** from the cylinder after it has done its work. This port 4 is in communication with the atmosphere, or a condenser. 1 is the valve rod by which the valve is moved back and forth across the steam ports 3 and 5. This valve rod is connected to the eccentric, from which it derives its motion. 7 is the piston against which the steam acts to rotate the crank or disc which is fastened to the engine shaft.

In the position of the valve shown in the upper diagram of the Fig 139, should the steam be admitted to the steam chest, which is a chamber in which the valve operates, then, as **both** the steam ports 3 and 5 leading to the ends of the cylinder are closed by the valve, no steam can pass into the cylinder and hence no force would be exerted upon the piston, and therefore all parts of the engine would remain stationary.

In the position of the valve shown in the lower diagram of Fig. 139, the engine is on the center, the left port 3 being slightly open and the piston 7 just beginning its **forward** stroke. By forward stroke is meant the moving of the piston from the head end to the crank end of the cylinder, that is, from the left to the right. 6

is the head end cylinder cover from which the piston i just beginning to move.

As the piston moves forward in the stroke, th valve will further uncover the left port 3, thus admittin more steam to act against the piston, and this admissio of steam will continue until the valve entirely uncover this port and again closes it. On the return stroke o the piston, which is from the crank end to the head end this port 3 opens to permit the steam in the cylinde which will then be behind the piston, to exhaust throug the port 4, the live steam then entering through th right port 5.

So we see that on the return stroke the process i reversed, the port 5 being for the admission of the steam and the port 3 for its exhaust. This motion of the valv distributing the steam alternately first to the left an then to the right, will continue until the steam is finall shut off from the engine by closing the throttle valve thus bringing the engine to a stop.

It is therefore seen that the piston in the cylinde of an engine is propelled back and forth by the expan sive force of the steam which is admitted alternately a either end of the cylinder, and acts first on one side o the piston to drive it forward and then upon the othe side to drive it back to the starting point.

As the steam is under great pressure, sometimes a high as 200 pounds to the square inch, the force actin on the piston at any given instant is enormous. In a engine with the cylinder 16 inches in diameter and wit 100 pounds average steam pressure acting upon it, th force will amount to as much as 20,100 pounds througt out the **entire** stroke of the piston.

After the steam has forced the piston to the er the cylinder, the valve opens the exhaust port and al

e steam to escape, or exhaust. All this must be done y the valve precisely at the right moment.

An engine running at a speed of 300 revolutions per inute, makes 600 strokes per minute, as the piston must ravel twice the length of the cylinder during each revlution of the crank. This means 600 admissions and 00 exhausts per minute, or 10 per second. Not only ust the valve move with this great **rapidity**, but also ith the greatest **accuracy**, as it must open the port to mit the steam, and then close it at the proper moent, and then allow it to remain closed long enough for e steam to expand should the valve have lap, and then ain open it for its discharge.

As the human mind and body are not capable of inking and acting with such rapidity, the valve must e operated **automatically**, which means **self-acting** from e forces within itself.

Expansion.—In order that the expansive properties f steam may be **fully utilized**, its admission to the cylder must be cut off **before** the piston arrives at the end f the stroke, thus allowing the remainder of the stroke be made by the force of the expansion of the steam one, unaided by the continuance of the boiler pressure. order to confine the steam within the cylinder after admission is cut off, the valve must continue to keep e steam port closed so that the steam cannot escape.

Cut Off.—This is the point of a piston's travel at ich the steam admission port closes, no further steam g admitted into the cylinder during the stroke.

With the valve shown in the upper diagram of Fig. this could not be done, the steam being admitted the e stroke of the piston, as the steam port could not losed by the valve until it started on its return e.

Outside Lap.—In order to cut off the steam befo[re] the piston completes its stroke, the edge of the val[ve] must be made **wider** than the steam port; and the di[s]tance that the valve overlaps the outer edge of the po[rt] when the valve is in its central position is called **outsi[de] lap.**

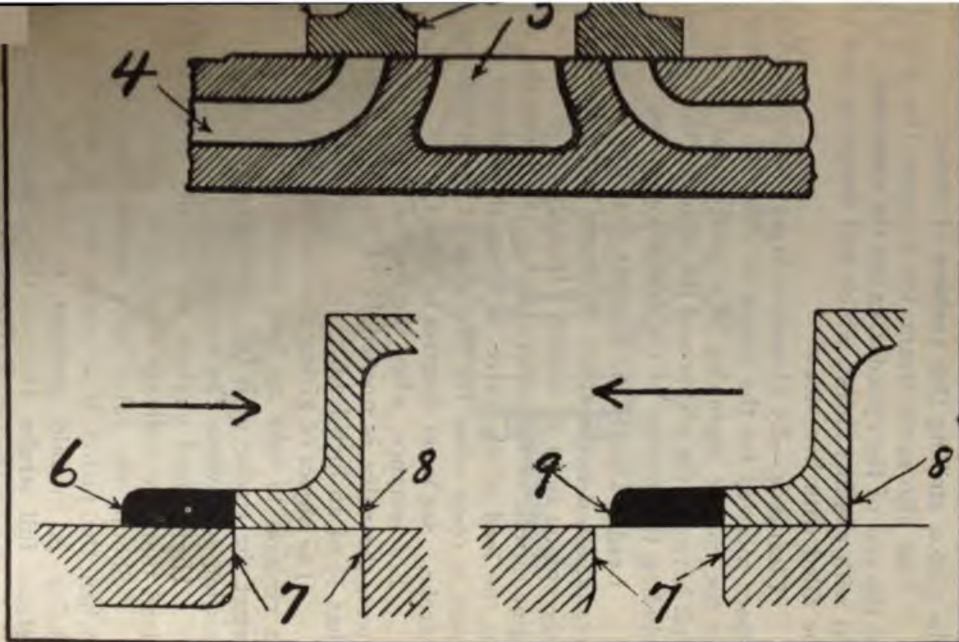
In Fig. 140 the valve is shown in its central positi[on] equally covering the steam ports, and the space 2 ther[e]fore represents the outside lap on the valve. This ou[t]side lap, much magnified, is shown by 6 in the lower di[a]gram of Fig. 140. The black space in this diagram re[p]resents the distance that the edge of the valve overla[ps] the edge of the steam port, and hence is called the ou[t]side lap of the valve.

The first valve shown in Fig. 139 did not do th[is] and in order to add this lap, the faces of the valve mu[st] be lengthened so as to overlap the steam ports as abo[ve] described. After the steam is cut off by this extra ed[ge] or lap 6, the steam is then confined and expanded in t[he] cylinder until the inside edge 8 of the valve comes ev[en] with the inside edge 7 of the steam port, at which i[n]stant the exhaust begins. See lower diagram of Fig. 1[40].

The object therefore of outside lap on a valve is [to] utilize as much as possible the **expansive** properties [of] the steam.

Inside Lap.—In Fig. 140, 3 represents the **inside l[ap]** on the valve, it being the distance that the valve ove[r]laps the **inner** edge of the steam port when the val[ve] is in its central position. The object of putting insi[de] lap on a valve is to close the exhaust port **before** t[he] piston reaches the end of the return stroke, thus holdi[ng] back some of the exhaust steam, and thereby in[creasing] the pressure at the end of the stroke of the pist[on].

The effect of this is to make the engine run



Section of Ordinary Slide Valve, Showing Outside and Inside Lap
Fig. 140.

smoothly, by bringing the reciprocating parts to rest b[y] the piston striking this **cushion** of steam.

This also saves steam, for it causes the waste roo[m] at the end of the cylinder, called the **clearance**, to be fill-ed with exhaust steam, which will therefore not have t[o] be filled with live steam.

Clearance.—By clearance in a cylinder is meant th[e] space allowed for the piston to clear the cylinder head[s] at the end or beginning of a stroke, that is, the spac[e] left between the piston and the heads of the cylinder, in-cluding the volume of the admission ports.

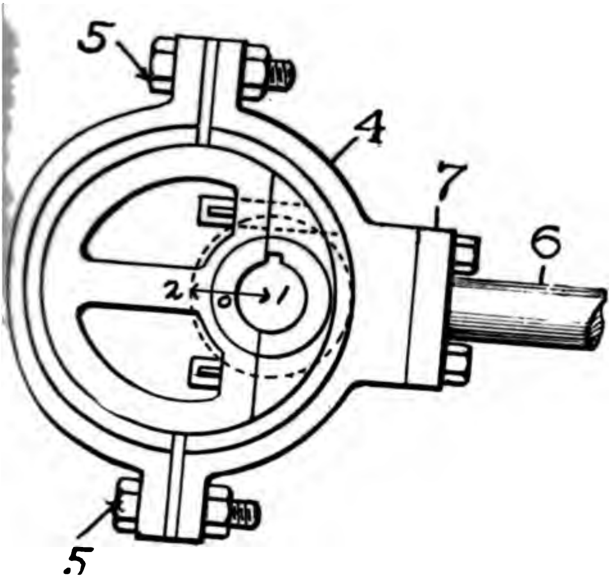
Lead.—This is the amount that the valve leads t[he] crank, for it is the space the steam ports are open whe[n] the engine is on its center. In Fig. 139 is shown an en-gine on one of its centers, and in the figure the space is the **lead** of the valve, it being the amount the stea[m] port is open when the piston is at the beginning of t[he] stroke. See lower diagram of Fig. 139.

For instance, when the engine is on one of its ce[n]-ters, the valve is opened ⅛ of an inch, we say that has ⅛ of an inch lead.

The **object** of giving a valve lead is not only to for[m] a cushion to take up lost motion, but it also helps **start** the stroke with full steam pressure, as well as a[s]-sisting to reverse the stroke.

High speed engines are usually given much mo[re] lead than the ordinary slow speed engine.

Should the valve have **neither** lap nor lead, th[en] when the piston is at either end of the cylinder, t[he] valve is in **mid position** so that the engine tak[es] steam **full stroke**, that is, the admission port rema[ins] open during the entire travel of the piston from one e[nd] of the cylinder to the other end. Steam is therefore a[d]-mitted and exhausted during the whole stroke of t[he]



The Eccentric, Showing Parts.
Fig. 141.

piston, which is most **wasteful** of steam, and for reason but **few** engines are now built which take s full stroke.

Principles.—As the above principles apply t valves of whatever type, size or description, they sl be thoroughly understood before proceeding furthe

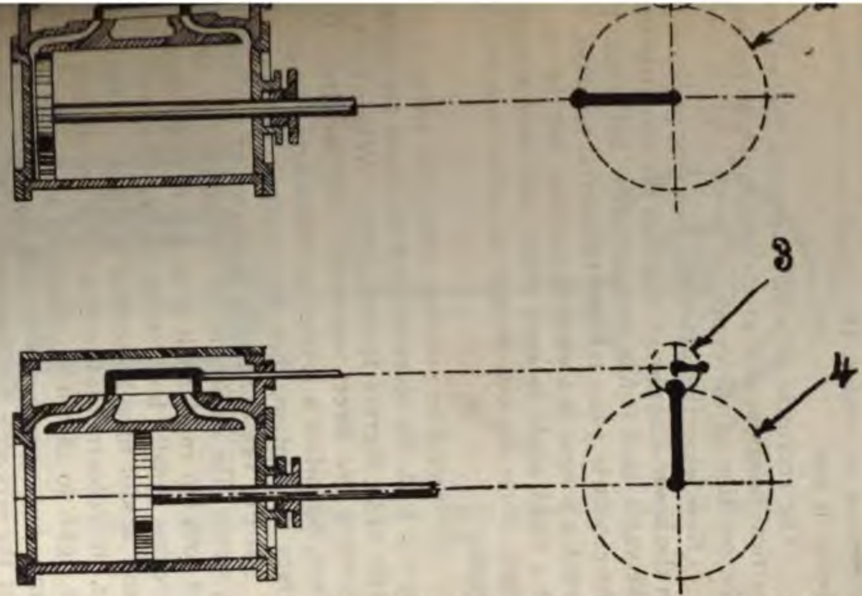
We therefore see that the **power** which operate steam engine is the **expansion** of the steam. In the way the gas engine is operated by the **expansion** mixture of gas and air burned in the cylinder; and ar or hot air engine, by the **expansion** of the oil or he air in the cylinder

Now, this mechanical work is obtained in all above forms of energy by the expenditure of **heat.**

As steam expands 1669 times its volume under mospheric pressure, that is, one cubic inch of water make one cubic foot of steam; the enormous powe the steam engine, which utilizes this priceless prop of steam, can be seen. While **all** steam engines are c ated by this expansive force of steam, the **full st** engines cannot utilize as much of this energy of s as the automatic cut off engine, which engine fills a **part** of its cylinder during each stroke with st and allows expansion to do the rest.

In the **automatic,** or variable cut off engine, s is taken at boiler pressure into the cylinder, not fo entire stroke, which would necessitate its being exh ed into the air at the end of the stroke without ex sion, but only for a **portion** of the stroke, usually half or less, except in some fixed cut off engines w take steam from one-half to three-quarters of the st

Angle of Advance.—In Fig 142 is shown the tion of the crank and eccentric when the valve **neither** lap nor lead. The upper diagram show



Position of Crank and Eccentric When Valve Has Neither Lap Nor Lead.
Fig. 142.

valve in its central position, covering both steam p and the piston at the end of the stroke. The engir therefore on center, the crank and the connecting being in line.

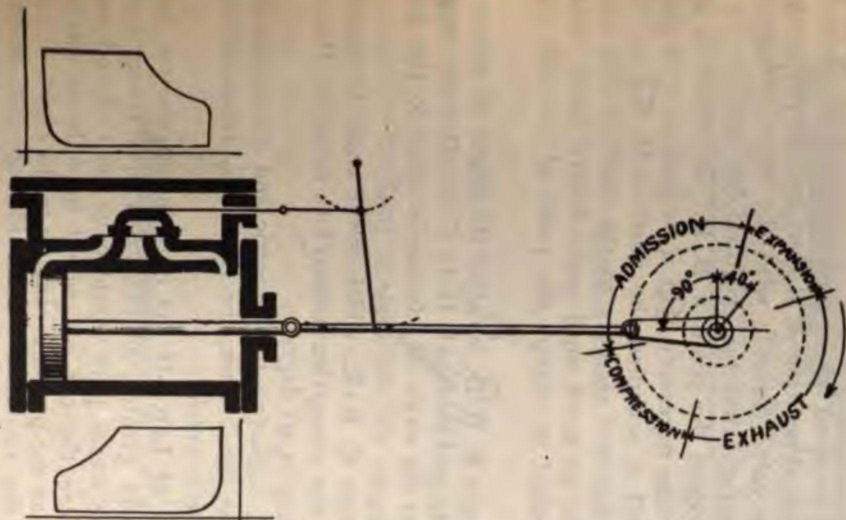
The eccentric 1, which operates the valve, is vertical position, and at a right angle, or 90 degrees the position of the crank.

Now when the piston moves to the position as sh in the **lower** diagram of Fig. 142, the eccentric has m the valve until it has uncovered the left steam port, the eccentric 3 has taken a horizontal position, while crank 4 is now in a **vertical** position, but the two are at a right angle to each other, and they remain at angle of 90 degrees during the entire revolution of crank.

We therefore see that when the valve has **nei** lap nor lead, the eccentric and the crank are **always** a angle of 90 degrees to each other. When the valve eccentric are **direct** connected, the eccentric **leads** crank, but when a reversing rocker arm is used, as i verses the motion, then the eccentric **follows** the cr

In Fig 143 the piston is shown at the beginnin its stroke, the engine being on center, but as this v has **both** lap and lead, it is no longer in a central pos covering equally both steam ports as before. Whil crank is still in a horizontal position, as shown in 142, the eccentric has moved from its vertical positic the right, so that it no longer is at a right angle to crank, but now forms an **obtuse** angle. The **dist** that the eccentric has been moved forward or **adva** is equal to the lap and lead that have been giver valve, and this angle is therefore called the **angle o vance.**

In Fig. 144-(1) the angle A. B. C. is the angle c



Position of Crank and Eccentric, When Valve Has Lap and Lead.
Fig. 143.

vance, in which B. C. shows the position of the ecc tric.

If there were **no** lap or lead, the eccentric would cupy the vertical position A. B., but in order to make edge of the valve coincide with the edge of the p it was necessary that the eccentric be moved forw until it occupied the position **B. D.** In order to all for **lead,** it was **necessary** that it be moved still furt forward until it occupied the position B. C., at wh point it is fastened securely to the shaft of the eng and remains so fixed until some future time wher may be desired to change the point of cut off, or lead.

The angle **A. B. D.** is called the **angle of advanc the eccentric,** and the angle B. D. C. is called the **angl lead,** so that the angle of advance is equal to the sun these two angles, viz., the angle A. B. C.

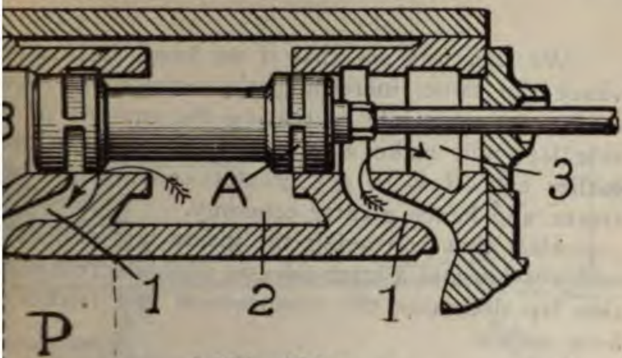
The angle **C. B. R.**, which is the angle between crank and the eccentric, is therefore equal to the an of advance, plus 90 degrees.

In Fig. 144—(1) the eccentric and crank are sh by the heavy black lines, the line B. C. representing **radius** of the eccentric.

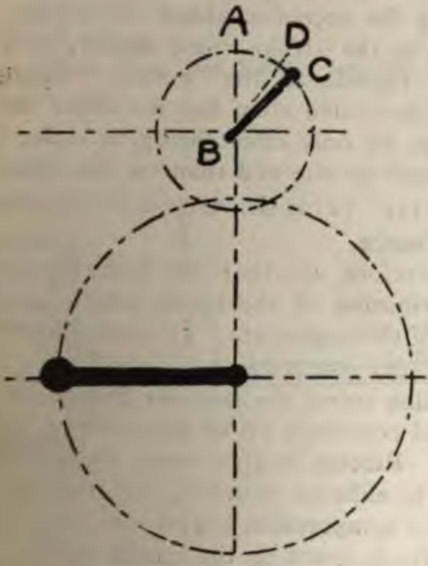
Effects of Lap.—If the outside lap shown in 143 had been greater, as the valve is moving tow the left, the steam port would have been closed **soc** and therefore the cut off would have been **earlie** the stroke, as the piston is moving to the right.

If on the contrary the outside lap had been then the steam port would have opened earlier and cut off would have been **later,** causing less expan of the steam, and a higher pressure at release.

If we **increase** the inside lap of the valve, the haust ports as can be seen in Fig. 143, will open l making compression to begin **earlier.**



A Piston Valve.
Fig. 144.



Angle of Advance.
Fig. 144—(1).

We therefore see that if we keep the angle of vance the same, increasing the outside lap causes earlier cut off, while decreasing the amount of the side lap, will make a later cut off. The effect of **earlier** cut off is to get greater expansion out of steam, and hence greater economy.

Also, that increasing the **inside** lap, causes gre compression and a later release, while decreasing the side lap decreases the compression and makes the lease earlier.

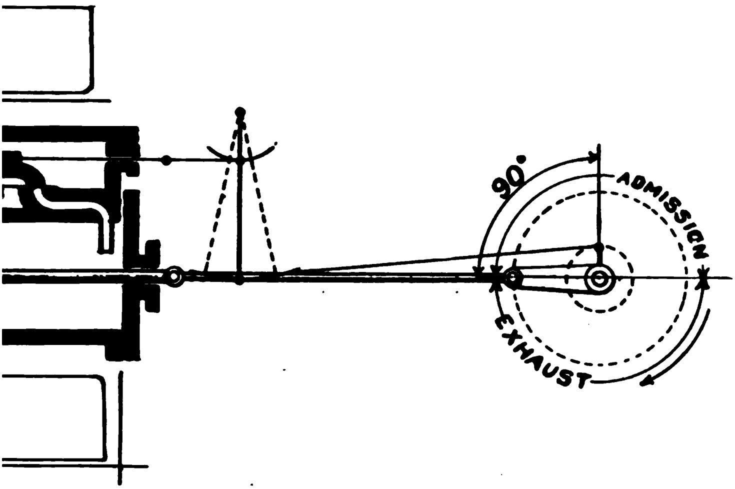
Increasing or decreasing the **inside** lap does not fect the cut off, and hence the expansion; but it a effects the **release** and **compression** of the steam.

Shifting the eccentric **ahead** or forward, makes the events in the stroke come **earlier**, and movin **backwards** retards all the events. Lengthening shortening the valve stem has no effect on the ac of the valve, its only effect being to make the lead cut off greater on one end than on the other.

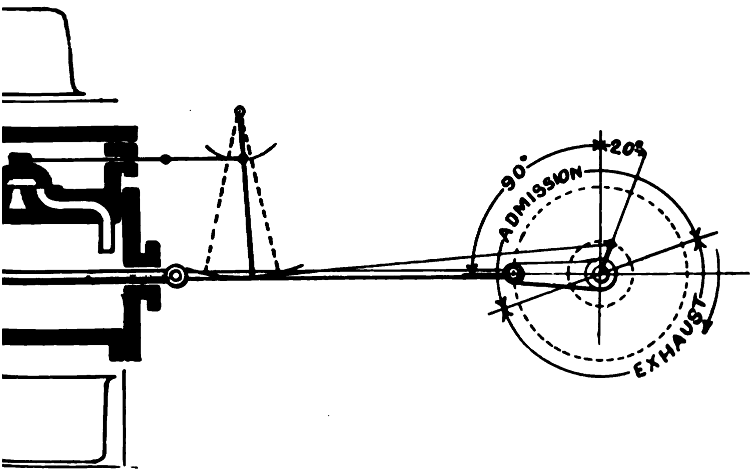
In Fig. 144—(2) is shown position of eccentric, and **angle of advance.**

We therefore see that the **four** important ev in the **distribution** of the steam which occur in e revolution of the engine are: (1) admission; (2) cut (3) release; (4) compression.

Admission starts the moment the steam port is covered, and continues up to the point of the **cut of** the steam. **Release** begins when the exhaust por opened to the **exhaust** chamber, and continues until closed, when **compression** begins and ends with the mission of fresh steam on the return stroke. Ex of the steam therefore continues from the instan off to the release of the steam by the opening of haust port.



When Valve Has Neither Lap nor Lead.



When Valve Has Lead.

ition of Crank and Eccentric, Showing Angle of Advance.

Fig. 144—(2).

Direct and Indirect Valve.—A slide valve is said to be **direct** when it opens the left port by moving to the **right,** which makes the valve take its live steam over its **outside** edge, and exhaust past the **inside** edge.

A valve is said to be **indirect** when it opens the left steam port by moving to the **left,** and closes it by moving to the **right.** This valve therefore takes its live steam over its **inside** edges, and exhausts past the **outside** edge of the valve.

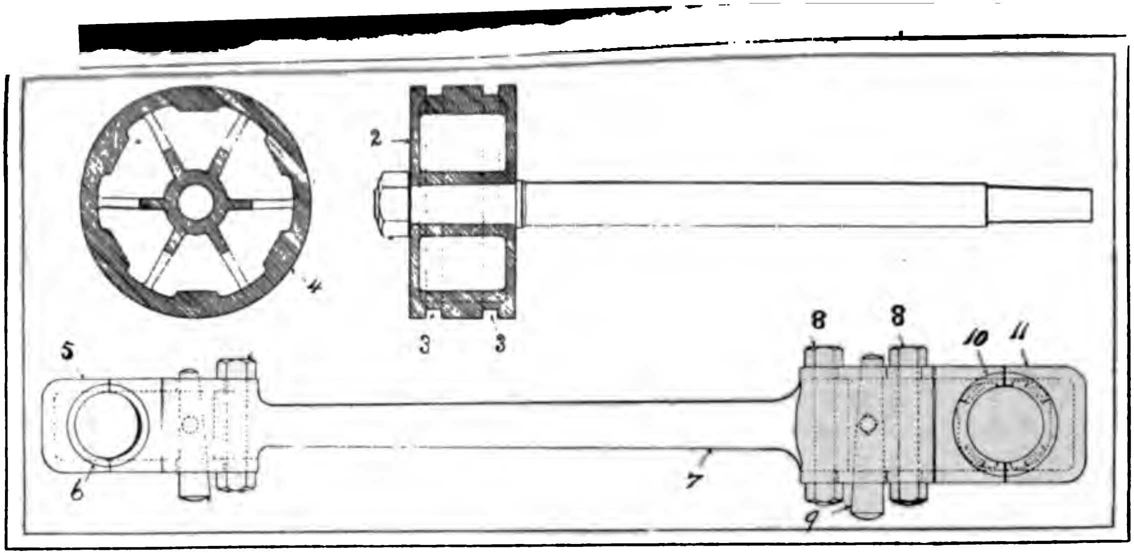
The plain slide valve which has been described in above figures, is therefore a **direct** valve, as it opens the left port by moving to the right, admitting steam past the outside edge, and exhausting past the inside edge.

The **piston** valve is an example of an **indirect** valve.

The Piston Valve.—The valve shown in Fig. 144 is a **piston** valve. It consists of a hollow cylinder moving back and forth in a cylindrical valve seat. The ports 1 extend clear around this valve. The live steam is admitted into the central chamber 2, and the exhaust steam escapes out of the two ends 3, 3. As shown in the figure, the engine is on its center, the piston P about to start to the right, and the valve therefore is moving to the **left,** thereby uncovering the **left** steam port, and thus allowing the steam to enter past its **inside** edge, making it an **indirect** valve.

To **increase** the admission of live steam, steam passes into the center of the valve through the channel A, and thence out into the left port. The **exhaust** steam escapes past the **outside** of the valve through the **right** port 3.

A piston valve is not **necessarily** an indirect valve, as these valves are often made **direct** acting, being then treated exactly as an ordinary slide valve. Such direct



Section of Connecting Rod, Piston Rod and Piston.
Fig. 145.

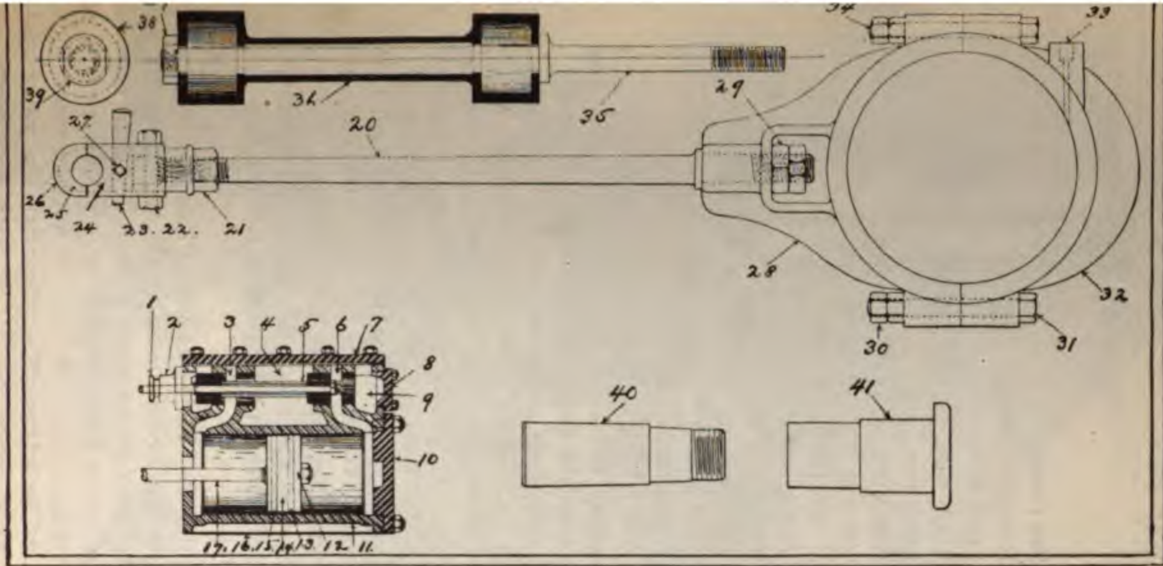
[redacted]

acting piston valves are not made hollow, their construction is the same as the slide va

In Fig. 145 is shown a section of connecting rod and piston.

In Fig. 146 is shown a sectional view (chest and cylinder, showing a piston valve. of the minor parts of an ordinary engine is numbers indicating same corresponding to th in the figure.

1. Valve stem stuffing box gland.
2. Valve steam stuffing box.
3. Steam port.
4. Exhaust chamber.
5. Piston valve.
6. Steam port.
7. Steam chest cover.
8. Valve chest head.
9. Steam chamber.
10. Cylinder head.
11. Cylinder.
12. Piston follower.
13. Piston ring.
14. Piston.
15. Piston ring.
16. Cylinder casing.
17. Piston rod.
20. Eccentric rod.
21. Adjusting nut.
22. Bolt for fastening the strap and brasse stem end of eccentric rod.
23. Key.
24. Brass boxes.
25. Brass boxes.
26. Eccentric rod strap.



Section of Steam Chest and Cylinder, Showing Piston Valve,
Eccentric and Rod.
Fig. 146.

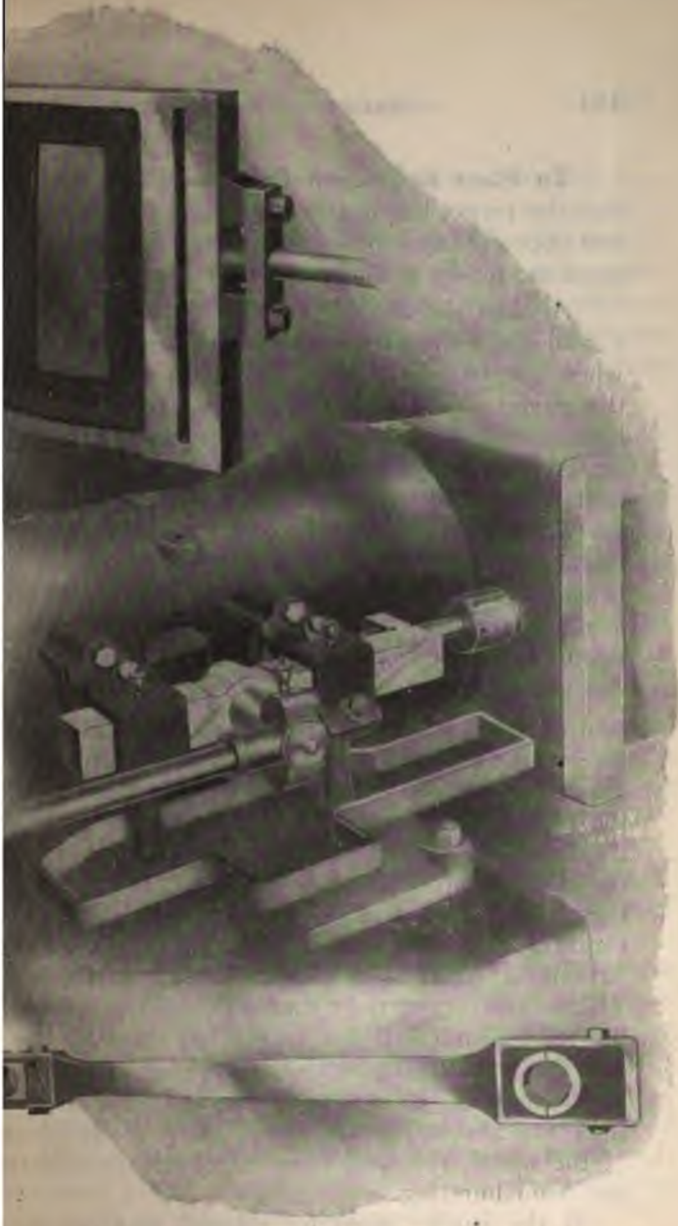
27. Set screw.
28. Eccentric strap.
29. Lock nut.
30. Lock nut.
31. Lock nut.
32. Eccentric strap.
33. Oil cup for eccentric.
34. Eccentric strap bolt.
35. Valve stem.
36. Piston valve.
37. Valve stem nut.
38. End view of piston valve.
39. Valve stem nut.
40. Wrist pin.
41. Crank pin.

Travel.—The **travel** of the valve is the total distance that it moves, and is equal to twice the radius of the eccentric. A valve with lap must be given more travel than one without lap so as to open fully each port to steam. Without lap the travel is equal to **twice** the port openings, as there are two ports to uncover. With lap, the travel is equal to twice the port openings **plus** the lap.

Increased travel means increased throw of the eccentric, and therefore a larger eccentric.

Lead does not effect the travel of the valve, as that is included in the port opening to which is added the lap of the valve.

Setting the Slide Valve.—Place the engine on a **dead center** and give the valve the necessary amount of lead; then turn the engine to the other dead center, and see if the valve has the **same** amount of lead; if so, it is properly set, but if the lead is **not** the same then the valve must be **adjusted** by means of the **valve rod** and nuts, so as to make the lead of both ends equal.



Valve, Connecting Rod and Valve, and Eccentric Connection.

Fig. 147.

To Place Engine on Center.—Place the engine so that the piston has nearly completed its outward stroke, and opposite some point on the crosshead make a mark upon the guide, as shown at E in Fig. 136.

Against the rim of the wheel place a pointer, as at C, and make a mark upon the wheel opposite this pointer when the crosshead is in line with the mark E upon the guide. Now turn the engine over until the crosshead is again in the same position on its **downward** stroke. This will bring the crank as much below the center as it was before above it, and the point F on the fly wheel will be opposite the pointer, and must be marked. Divide the distance between F and C accurately and **midway** between them, mark the point H. Now bring H opposite the pointer, and the engine will be upon the **true center.**

Fly Wheel.—There are two instants in each revolution of the crank when the directions of the crank is in line with the connecting rod, and the position of the crank pins at those instants are called dead points, as the piston is momentarily at a stop in order to change its direction when it reaches these points. In order to diminish the irregular action caused by the existence of these dead points and also to carry the engine over the centers, a **fly wheel** is used, which prevents such fluctuations in speed as would be caused by these centers. The momentum of the fly wheel carries the shaft around until the piston can again be acted upon by the steam. The heavier the fly wheel, therefore the steadier will be the motion, but it is undersirable to use larger wheels than are absolutely necessary, on account of the cost of the metal, the weight on the bearings and the danger from bursting.

If the engine must be stopped and reversed fr

quently, it is better to use two or more cylinders connected to the same shaft, and in this way the use of a fly wheel can in many instances be avoided. When two cylinders are used, the cranks are placed at such angles that when one is exerting its minimum force, the other is exerting its greatest power. In this way the engine can be carried over the dead centers without the expense and inconvenience of having a fly wheel.

The fly wheel of an engine in addition to serving the purpose of a balance wheel, may also be used as a belt wheel and a governor wheel. As a balance wheel it must have, as we have seen, considerable weight to carry the engine smoothly over the centers by absorbing or giving out sudden excess and shortage of power.

As a **belt** wheel it is used to deliver the power of the engine to the line shaft through the belt, and as a **governor** wheel it serves to carry the automatic governing mechanism.

When it is necessary to use an unusually heavy fly wheel, or one located at a distance from the engine frame, an extra bearing is used to carry the outside end of the shaft, so as to relieve the strain on the main bearing.

To **reverse the motion** of a slide valve engine place the engine on the center, noting the amount of the **lead** on the valve. Then slacken up the set screw of the eccentric and turn it ahead on the shaft, that is, the same way it has been running, until the valve has moved to the extreme of its travel, when it will be exactly opposite its original position. Lastly, move it back until it has the same lead as before and tighten the set screw.

Lining an Engine.—First **strip** the engine. To do this take off both cylinder heads, then take out the follower-head, piston rings and bull ring, and disconnect the piston from the crosshead and crank pin.

Now take a slotted stick and place it on one the studs on the end of the cylinder furthest fr crank. Draw a fine string over the stick and t the center of the cylinder, and attach it to an stick fastened at the other end of engine bed floor. Take a thin stick, not more than ¼ of a thick, and about ½ inch shorter than the diame the cylinder. Stick pins in each end of the sti that the pins can be easily forced in or drawn c suit the adjustments. With this stick, **center** th at each end of the cylinder from four opposite sid moving the stick around in the counter bore of th inder. While only two adjustments are necessary the string in the center of the cylinder, it is b measure around from four opposite sides in order cure accuracy.

This line is then the center line of the engin all other parts of the engine have to be adjusted

The shaft should be **first** adjusted by placing at right angles with this line. This is done by u vertical line. It can then be **leveled** by placing on the shaft.

The **guides** are adjusted by laying a **straigh** across the face of the lower guide, and measuri distance from the straight edge to the center l both ends of the guides. Should there be any diff it must be adjusted by adjusting the guides.

In this way all parts of the engine are ad or lined, including its frame or bed.

Horse Power of an Engine.—The **unit** of power is the **foot pound**, by which is meant one of force exerted through one foot of space. **One** power is the raising of 33,000 foot pounds per mi 550 foot pounds per second.

card of the engine. This diagram, or card, which is taken during one or more revolutions of the engine will show the exact pressure acting on the piston throughout the entire stroke, and from which the mean effective pressure can be calculated.

The device or instrument used for making this diagram, or cards, is called **an indicator,** and it will be described in a later chapter.

Throttling and Automatic Engines.—The ordinary slide valve engine, as has above been described, is what is known as a **throttling engine,** as its regulation is controlled by means of a throttling valve. With a throttling engine the point of cut off is **fixed,** and the speed is regulated by a throttling valve in the steam pipe, called the governor valve, which admits more steam as the load increases and less as it decreases. This **wire-draws** the steam as it is called, which is not only wasteful of fuel, as the full pressure of the boiler cannot be utilized, but it also prevents any perfect regulation of the speed of the engine.

Automatic Engine.—This engine has a **variable** cut off, which permits full boiler pressure to be utilized, as the steam is cut off the moment a sufficient amount has been admitted to the cylinder to complete the stroke, allowing the remainder of the stroke to be completed by its expansion.

Classes.—All engines are divided into these **two great classes,** the chief difference being in the principle of the **regulation** of the steam supply.

Uses.—The first class, or the throttling engine, is mostly used for small mills and factories, on account of its simplicity and low first cost. The second class, or the automatic engine, while it is much more complicated, is much more **economical** in the use of steam, and

is therefore used in larger plants, or wherever fuel is expensive.

To Increase Horse Power of an Engine.—The horse power of an engine can be **increased** in three different ways, viz.:

(1) By increasing the **diameter** of the governor pulley, which increases the **speed** of the engine, and thereby the power. This refers to pulley on governor shaft.

(2) By a **later** cut-off, which requires a new valve, and a change in the eccentric and travel of the valve.

(3) By increasing the boiler pressure.

While the **power** of the engine is increased, the **amount** of steam used, is also increased.

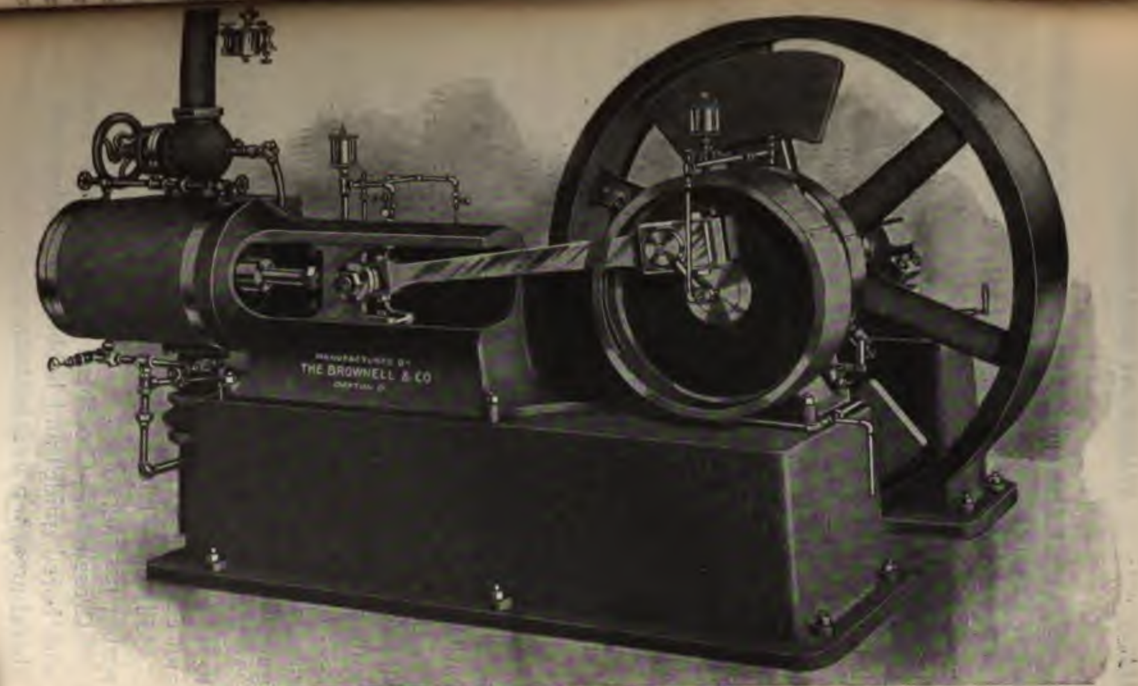
Right Hand Engine.—This is an engine, the fly wheel of which is to the **right** when looking at the engine facing the cylinder.

Running Over.—An engine is said to **"run over"** when the top of the wheel runs away from the cylinder, and to **"run under"** when the top of the wheel runs **toward** the cylinder.

Most engines are built to **"run over,"** as the pressure of the cross-head is then always **downward** upon the guide. When the engine "runs under," the thrust of the cross-head is then upon the **top** guide on both the outward and inward strokes, which is likely to cause the cross-head to **lift** when subjected to the thrust, and then fall by its own weight on the centers, making the engine pound.

THE BROWNELL SLIDE VALVE ENGINE.

Type.—As will be seen from Fig. 148, this engine is of the **self-contained side-crank type,** that is, the outer bearing is cast solid as a part of the bed. This is a feature of great importance, as the engine can be shipped in perfect alignment and set in position ready for running in less time than required for other types of engines. Furthermore, this work requires no expert me-



The Brownell Slide Valve Engine, with Shaft Governor.
Fig. 148.

chanic, as all fine adjustments are made at the factory before shipment.

Proportions.—The crank shaft is made extra heavy, the length of main bearing is approximately twice the diameter of the shaft, and the length of outer bearing is approximately three times the diameter of the shaft, and all other parts are proportionately large.

Material.—The crank shaft, pins and piston rod are hammered steel, the connecting rod is a solid steel forging, the main bearings are lined with first-class babbitt and scraped to a true fit. The cross head is of the Corliss type, and has babbitt lined adjusting shoes top and bottom.

SPECIFICATIONS FOR AN ORDINARY SLIDE-VALVE STEAM ENGINE.

We hereby propose to furnish you with .... slide-valve steam engine manufactured by ...., in strict accordance with the following detailed specifications:

Size and Horse Power.—The engine shall be our slide-valve (self-contained or detached) side-crank type with overhanging cylinder ...... inches diameter and .... inches stroke. With .. pounds boiler pressure and running a..............revolutions per minute the engine will develop ......I. H. P.

Valve.—Valve to be accurately fitted and scraped to its seat, and guaranteed steam tight, with ample steam and exhaust ports.

Piston.—The piston to be of the solid type with spring packing rings.

Crosshead.—Crosshead to be of the Corliss type, with bored guides and babbitt lined adjustable shoes of liberal area, top and bottom.

Connecting Rod.—The connecting rod to be a solid :el forging with ends mortised to receive boxes. The x at crosshead end to be phosphor bronze, at crank d of cast iron lined with genuine babbitt.

Crank Shaft.—The crank shaft to be of the best iality hammered steel ...... inches diameter, turned ue and nicely finished, and free from flaws or other imerfections.

....

Journals.—The bearings to be adjustable and lined rith the genuine babbitt metal, accurately scraped to rue bearing surface. Crank bearing ...... inches long, uter bearing ...... inches long.

Wheel.—Band fly wheel to be ...... inches diamter and .... inches face. Weight about .... pounds.

Pins and Rods.—The crank pin, crosshead pin, valve od and pin, and piston rod to be of hammered steel, ighly finished and properly proportioned for the required ervice.

Cylinder Jacket.—The cylinder to be provided with at sheet steel jacket.

Trimmings.—Engine to be furnished with first-class rottling governor, with automatic stop, throttle valve ith nipple, sight feed cylinder lubricator, full set of ght feed oil cups, centrifugal oiler for crank pin, cylinr drip valves and set of wrenches.

....

....

....

Speed and Hand.—Engine to be ...... hand and to ...... at ...... revolutions per minute.

Finish.—Engine to be primed, rubbed down and fin-

ished in a hard varnish paint, green or maroon, at optio of purchaser. All necessary parts to be polished.

Guarantee.—We guarantee the above engine to b equal in efficiency and durability to any engine of it type and class manufactured. We further guarantee al parts free from defects of design, material or workman ship.

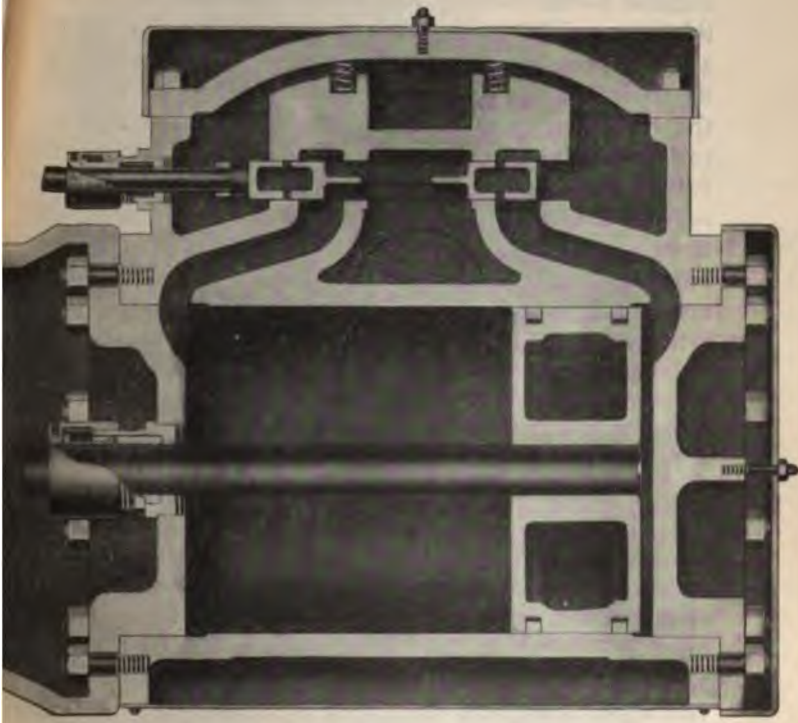
Test.—Before leaving factory engine will be thor oughly tested under steam and indicated to properly se valve and adjust all parts under actual working condi tions.

Drawings.—The necessary drawings for preparin foundation and erecting engine will be furnished free charge.

THE BROWNELL AUTOMATIC ENGINE.

Frame.—The frame of engine, as seen from Fig. 14 is a modification of the well known Tangye type, t principal change being in the adoption of the Corliss ty of crosshead with circular guides. The main bearin are unusually liberal in proportion, and are provided b neath with oil reservoirs, from which the bearings ceive a liberal and continuous supply of oil whene engine is in motion.

Governor.—Referring to Fig. 148, it will be seen th the **governor** consists essentially of the single weigh arm, swinging on a pivot pin. Fastened to this arm the eccentric which drives valve. As the weight a assumes different positions due to changes in load, **center of eccentric** is brought nearer to or farther fr the shaft center, thereby regulating travel of valve a admission of steam, in proportion to work requir There is an entire absence in this governor of the us



Sectional View of Balanced Slide Valve.
Fig. 149.

complication of links, dash pots and other interlocking devices.

Valve.—The valve shown in Fig. 149 is a thin rectangular ported casting, finished on both sides to an exact thickness. This valve works between the valve seat and a heavy pressure plate, which removes the pressure from its back, making it perfectly balanced. The weight of the valve causes it to wear down slightly, but this wear can cause no leak of steam, as is the case with the piston valve. This construction necessarily requires the greatest skill and accuracy in its production, making it much more expensive than other forms. Its great advantages, however, fully justify its increased cost. Provision is also made for relief in case of a charge of water getting into cylinder, thereby preventing an accident.

Cylinder.—The cylinder is cast from a special mixture making a close-grained iron which takes a high polish and which has great tensile strength. The cylinder is bolted direct to engine frame, the end of frame forming the front cylinder head.

Piston.—The piston is a single casting, cored very thin, and is braced with ribs to make it strong enough for any legitimate strain. It is shrunk on rod, and rod riveted over, on 10 and 11x12 engines, while on larger ones, it is held in place by a nut on end of rod. The wearing surface is very liberal. The piston is packed by two elastic cast iron rings, one near each end, while another ring of babbitt is poured in chamber in center.

In Fig. 147 is shown views of the valve, connecting rod and eccentric connection.

THE JUNIOR VERTICAL ENGINE.

Fig. 150.

Construction.—From an inspection of the sectionl view shown in Fig. 151, it will be seen that the **Junior**

ont View of the Junior Vertical Engine.
Fig. 150.

Engine consists in general of a pair of vertical cylind bolted to the top of an enclosed crank case, the latt serving the double purpose of a rigid pedestal for the e gine and a receptacle for the lubricating material.

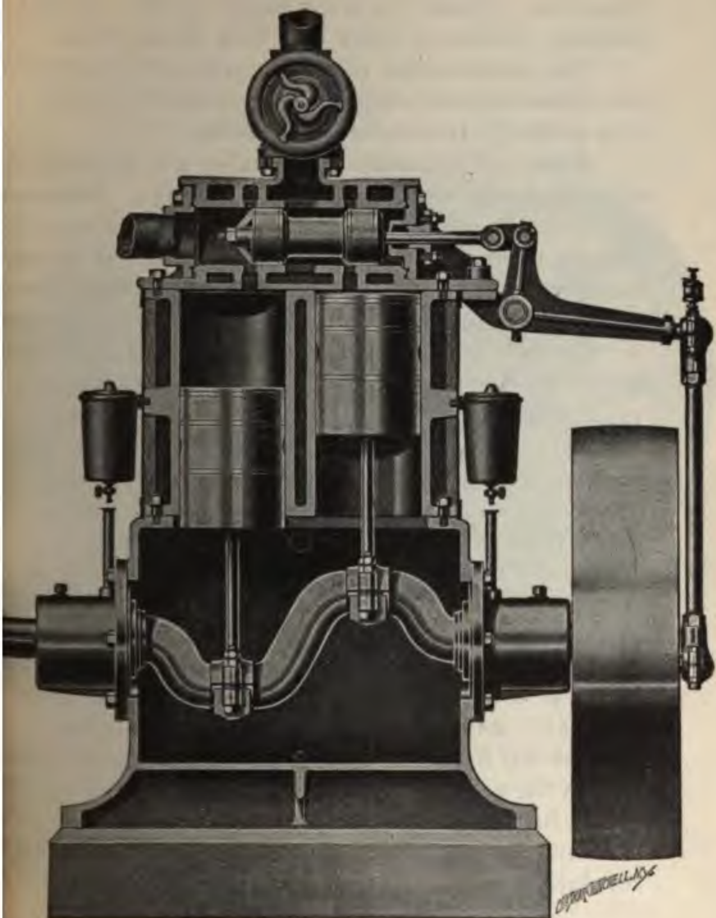
Steam Chest.—The steam chest, containing the si gle **piston valve** for effecting the steam distribution, bolted horizontally across the top of the cylinders, m tion to the valve being communicated through a b crank from the governor carried on one of the fly whee Spring relief valves in the front side of the steam che communicating with the ports leading to the cylinde furnish ample protection against shocks from sudd charges of water coming over through the steam pipe.

Bolted to the ends of the crank case are the cra case heads, which serve to support the main beari shells and at the same time to cover openings in eit end of the crank case to permit the introduction or moval of the shaft.

Main Bearings.—The main bearings are plain c iron cylinders lined with genuine babbitt metal. Th are turned on the outside concentric with the bore, fit accurately into the crank case heads, where they secured by set screws.

The pressure on the main bearings being alw downward, when the babbitt is worn nearly through the lower side the upper surface is still intact. shells may then be turned over, bringing the unw part into service and making the bearings for all tents and purposes as good as new.

Piston.—The piston, which also serves the purp of crosshead, is of the well-known trunk pattern, ve long in proportion to its diameter. A long piston is le liable to leak steam than a short one, and it does n



Sectional View of the Junior Engine.

Fig. 151.

allow the cylinder to wear larger in the middle. The packing consists of three cast iron spring rings.

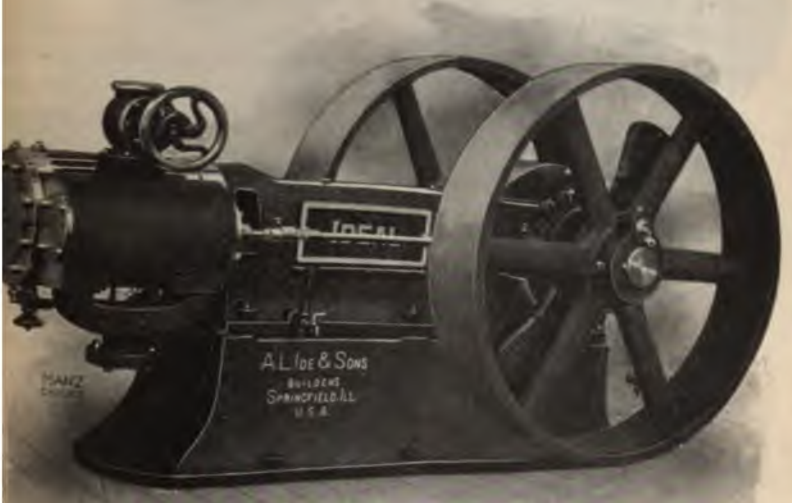
The piston wrist pin, with which the upper end of the connecting rod engages, is case-hardened and ground to a perfectly true cylindrical surface.

Valve.—The action of the valve will be easily understood from the sectional view in Fig. 151. Steam entering fills the annular space surrounding the neck of the valve. When the parts are in the position shown, the valve is moving toward the left, establishing communication between the steam space and the left hand cylinder through the left port, the left hand piston just starting on its downward stroke. The right hand end of the valve has begun to uncover the right port, so that the exhaust can pass up and through the valve, which is **hollow,** to the exhaust pipe. As the revolution progresses, the valve reaches the limit of its travel toward the left and starts back, covering the left port again, at a point determined through the governor by the load, allowing expansion to take place in the left hand cylinder. Continuing its travel toward the right, the valve covers the right port, so that a portion of the exhaust steam is compressed to fill up the clearance spaces. A little later, and just before the revolution is half completed, the left hand end of the valve uncovers the left port, so that the exhaust may have free exit when the left hand piston begins its upward stroke. A similar cycle of operations now occurs in opposite cylinders, completing the revolution.

THE IDEAL AUTOMATIC ENGINE.

Fig. 152.

Construction.—The accompanying cuts shows this engine as it appears with the standard equipment,



The Ideal Automatic Engine.
Fig. 152.

adapted to drive any kind of machinery by belt transm sion from one or both pulleys.

Accessibility.—Among the many features wh give distinction to the Ideal Engine, accessibility to working parts and the ease of making adjustments serve mention.

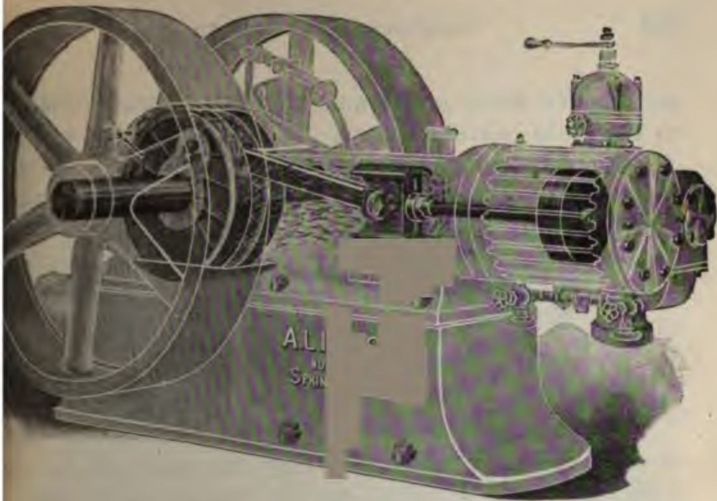
Doors in Both Sides of Frame.—All working pa are easy to reach. A removable door in each side the frame allows complete access to the cross-he wrist-pin and all adjacent parts.

Hinged Hood.—The hinged hood over the cra discs is light to lift, supports itself when raised a gives complete access to the crank-pin and boxes.

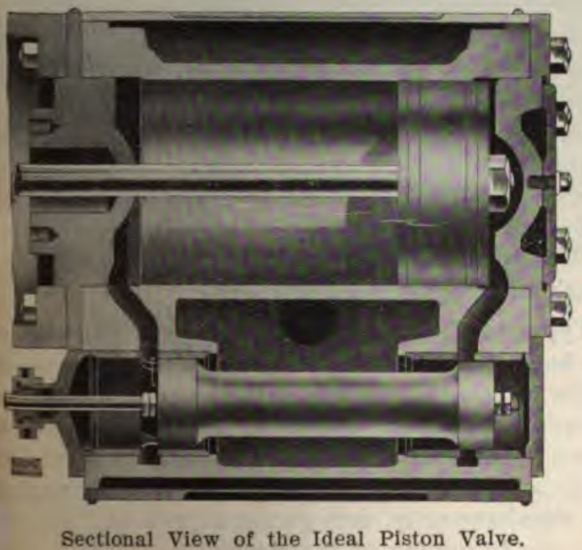
Piston-Rod Stuffing-Box.—The piston-rod stuffi box is enclosed in a chamber by itself, having hand op ings at either side. The gland may be adjusted wh the engine is running, without fear of injury from reciprocating parts through careless handling wrenches.

Oil Cups.—The eccentric is oiled from a self-filli cup attached to the hood, and provided with droppi attachment. No oil cups are used, the engine being s oiling.

Mode of Operation.—Fig. 153 shows the mode of eration of the self-oiling system. The frame of the gine and the hood over the crank-discs form an tight enclosure or casing. There is a depression in frame under the crank to provide a reservoir for into which the crank-discs dip. Oil adheres to t discs, and in the course of revolution is cast therefro by centrifugal force. A copious supply is cast ba upon the cross head, and a large quantity is thrown into receptacles provided in the hood above the disc



The Ideal Self-Oiling System.
Fig. 153.



Sectional View of the Ideal Piston Valve.
Fig. 154.

and thence flows in streams through suitable channels to the main bearings, crank-pin and eccentric; from all of which distributive points the oil returns by gravity to the oil reservoir, so to be used over and over again.

Valve Mechanism.—Fig. 154 shows the valve mechanism of single engine. The valve is driven centrally in a direct line with the eccentric, with the intervention of only one joint, and without the use of slides, rocker-arms, offset or any of the other complications so generally employed.

Adjustable Ball-Joint.—The one joint in the valve-driving mechanism is formed by the combination of a hard steel ball attached to the eccentric-rod working within a bronze socket attached to the valve-rod. It is adjustable by means of a set-nut, which fixes the distance between the two halves of the socket.

Compound Cylinder and Valves.—Fig. 197 shows valves of the compound engine. The cylinders of Ideal Compound Engines are arranged tandem-wise, the low-pressure cylinder being bolted to the end of main frame, and the high-pressure cylinder immediately to the end of low-pressure cylinder. Steam from the high-pressure cylinder has a short, direct passage into the low-pressure cylinder, without suffering loss of heat by passing through connecting pipes or receiver.

Types of Valves Used.—The high-pressure cylinder has a **hollow piston** valve, and for the low-pressure valve in order to bring it into line with the high-pressure valve and reduce clearance spaces to a minimum, has been adopted a **flat balanced valve,** traveling under a cover and so arranged that steam is admitted through two ports simultaneously, thus giving a quick and wide opening at the beginning of the stroke.

The Ideal Inertia Governor.

Fig. 155.

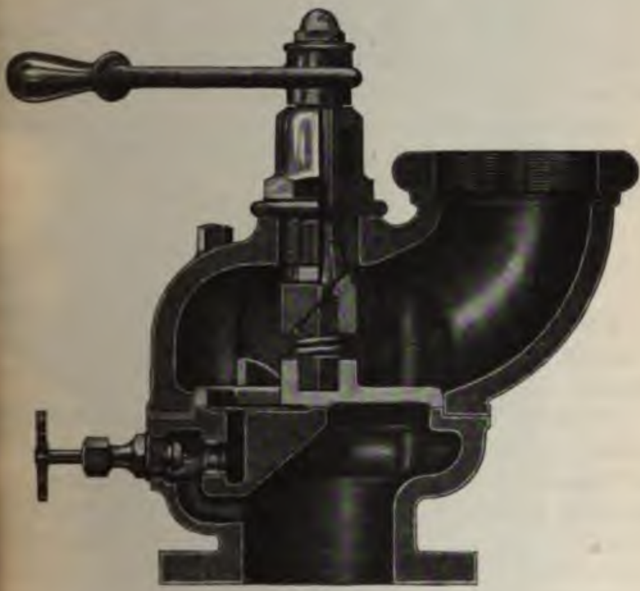
Details of Valves, etc.—The cover of this valve held in place by springs, and will lift and prevent e cessive pressure in the cylinder from water or oth causes. Both valves are perfectly balanced, and wi full boiler pressure can be moved by hand with eas Stuffing boxes between the two cylinders are dispens with entirely, being replaced by a long sleeve of an frictional metal. This sleeve is light, and free to a just itself central with the rod. Grooves are turned the inner surface so as to form a water packing.

Durability of Metallic Sleeve.—As the sleeve is fr to adjust itself to the rod, the only wear that can co upon it is due to its own weight, which is so little th with the perfect alignment between cylinder and guid insured by this form of construction, the wear is imp ceptible. Experience has proven that, with the leng of bushings employed, there is no leakage of steam, t time occupied by the piston in making a stroke bei so short and the travel of the rod being opposite to t direction in which steam tends to flow.

Ideal Quick Closing Throttle-Valve.—This specia shown in Fig. 156 has many attractive features, as w as several positive advantages over the usual form screw throttle-valve.

It is opened or closed by throwing the lever han through a quarter turn, which enables the engineer shut steam off from his engine instantly in case of emergency. A small bipass valve is for use in warmi up the engine and starting it slowly.

No Packing Required.—The valve-stem of both t main valve and the bipass are self-packing; that is, th are equipped with self-seating metallic cones, wh avoid the use of wick packing or any other form of structible packing.



Quick Closing Throttle Used on Ideal Engine.

Fig. 156.

The valve-seat is completely accessible upon the removal of the bonnet.

Ordinary Throttles Source of Annoyance.—A source of great annoyance to the engineer is the common everyday throttle-valve supplied with many automatic engines, owing to the **packing** of the valve stem. This must be done frequently to prevent leakage of steam, oil and water.

Inertia Governor.—In Fig. 155 is shown the governor used on this engine, which is the ordinary form of a Rites inertia governor.

THE CHUSE CENTER CRANK ENGINE.

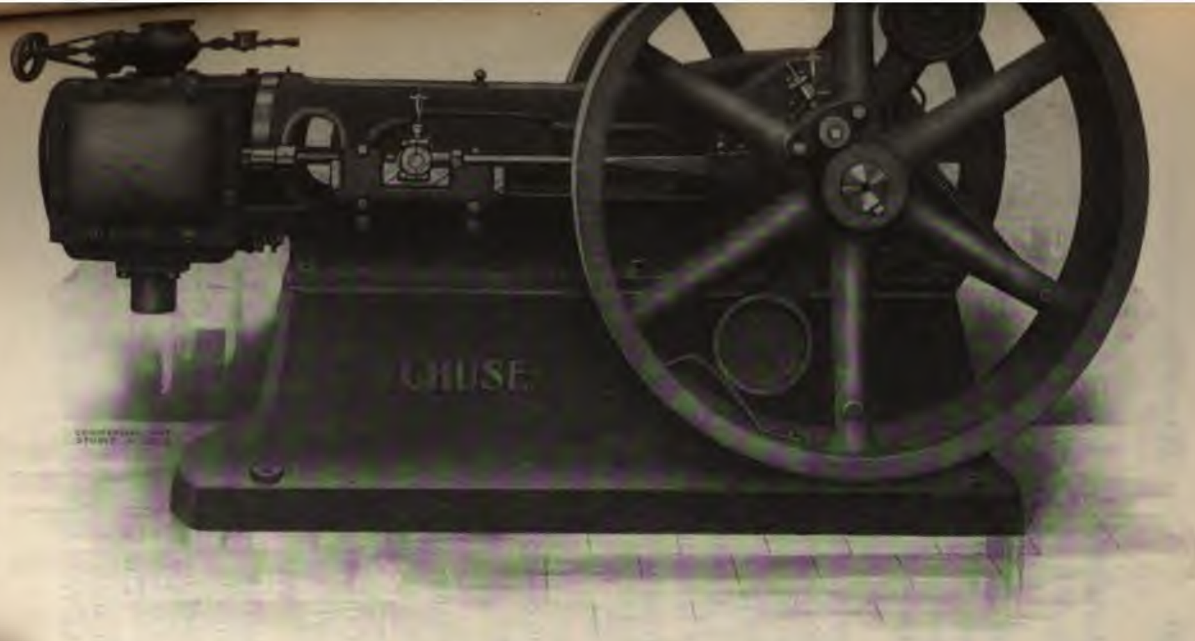
Fig. 157.

Construction.—This engine is a self-oiling, automatic cut-off engine, that presents a good combination for strength, durability and economy.

Frame.—The frame is of the box type and has bored guides, which is best suited to withstand the vibrations and strains upon it, as it forms a column, with the working parts moving down its center axis. It is absolutely oil tight and dust proof, yet it is instantly accessible to all inner parts by means of a crank cover and two large side doors. One of these doors has a slot on the top to accommodate an indicator motion.

Governor.—The "Rites" inertia governor is used on this engine.

Lubrication.—The engine is strictly self-oiling. Every bearing on the engine (with two exceptions) is automatically oiled with the oil contained in the bottom of the crank case. By this means, the journals, crank pin, cross-head pin, guides, eccentric straps and valve stem slides, receive a copious and continual flood of oil.



The Chuse Engine.
Fig. 157.

which after being used, drains back into the crank sin, and is used over again.

This arrangement reduces the wear to a minim and makes the engine exceedingly free running saves the attention necessary to be given to a dozen more oil cups. Grease cups are used on the gover spindle and valve stem slide ball joint.

A separate chamber in the frame with two stuff boxes prevent the leakage from the piston rod stuff box, from mingling with the lubricating oil contai in the engine frame, which preserves the life and e ciency of the oil.

Cylinder.—The cylinder is made of hard close gra ed iron, of special mixture, and the walls are made th enough to safely stand reboring several times. It bolted directly to the frame with ground steam tig joint. The cylinder head is also fitted with a grou joint and is encased in a highly polished cover, that r duces condensation and keeps the nuts from collecting and dust.

Very short direct ports are used, which reduce t friction to the passage of steam, and also reduces t clearance to the lowest amount that can be handled by single valve, variable cut-off engine. The high econon of this engine is largely due to this careful design of t ports and clearance.

Piston.—Is a deep hollow casting well ribbed, but light as is consistent with proper strength. It is fitt with two snap packing rings. The piston rod is turn from hammered nickel steel bars, and is highly polishe It is fastened to the piston with a lock nut.

The Connecting Rod.—Is solid steel, and is adjust in such a manner by wedge and keys, that the length the rod does not change appreciably with wear. T

aller sizes are fitted with removable hard brass bear-
gs, and the larger sizes are fitted with cast steel shells, ed with the best genuine babbitt.

Cross-Head.—Is a heavy steel casting of compact sign, and is fitted with cast iron shoes. The lubrica-n of the cross-head and guides is so perfect, and the earing surface so ample, that the wear is scarcely per-eptible.

Valve and Balance Plate.—The valve is of the **flat ulti-ported pattern,** and is balanced by a heavy balanc-ing plate, held in position by springs and the pressure of the steam. This valve will lift from its seat to relieve any entrained water, thus rendering the use of safety relief valves or diaphragms unnecessary.

The under side of the balancing plate is an exact du-plicate of the valve seat, and is so adjusted that it balan-ces the valve perfectly in all positions of its travel.

As both faces of this valve are vertical, and as the valve rides on its lower edge, the seats are relieved from wear due to the weight of the valve, and as the valve is perfectly balanced for steam pressure, very little wear occurs on the valve seats. This construction causes the valve to remain tight longer than any other type.

All valves are fitted to their seats under steam, and all the faces are scraped until they are perfectly true to each other, while under the heating and warping action of the live steam.

Valve Stem Guides.—It is very important that there should be a means of transmitting the angular motion of the eccentric rod to the valve stem in such a manner that it will move through the stuffing box without vibration. A slide is the only means of obtaining this exactly, and a very convenient and substantial slide and bracket is used on this engine.

The T head on the valve stem permits the
ing removed without disturbing the setting of t
The lock nuts on the other end of the stem p
convenient means of outside adjustment, and o
ing it securely to the valve slide.

The stub end on the eccentric connection r
tached to the valve stem guide by means of a s
ing ball and socket joint, which adjusts itself to
tion of the eccentric and is lubricated by a gr
Oil from the engine frame is fed continuously
cup shown on top of the slides, and runs down
feed holes to the grooves shown on the upper ed
slide, and thence through the bearings. A bra
rounding the bottom of these bearings cond
waste oil back into the engine frame.

CHAPTER XVI.

GOVERNORS.

Their Use.—A governor is used to **regulate,** or keep constant, the steam power of an engine. As the load on an engine constantly **varies,** some means must be provided by which the steam supply can be regulated in proportion to the load on the engine, so that its power and speed can be kept constant with the load.

Methods.—This is accomplished by the governor on the steam engine in two ways, viz.: (1) by regulating the **pressure** of the steam admitted to the steam chest: (2) by altering the **amount** of the steam admitted to the cylinder, which is done by **varying** the point of cut off of the steam supply.

Almost all governors depend for their operation upon the **centrifugal force** that is developed in a weight made to revolve around an axis outside of its center of gravity. The weight that is made to revolve, is so suspended that the centrifugal force developed by its rotation is opposed by a counteracting force or resistance, which force is usually a weight or springs, and whether the one or the other is used, determines **the type** of the governor.

Operation.—When the speed of these revolving weights increases, **the** centrifugal force also increases, and the weight **tends** to move **outwards** and **upwards,** but this force is opposed by the resistance of **gravity** also acting upon **the** weight. Should the speed of the engine become **excessive,** this counteracting force is not sufficient to hold **the weight** in its former path or plane of circuit, and the **upward** motion of the **weight** closes the regulating **valve, lessening** the steam pressure admitted to the **steam chest,** and in this way decreasing the

speed of the engine. As the speed of the engine de**creases,** the centrifugal force becomes less than the op-posing resistance or counteracting force, and the weigh is forced **downwards** and towards the axis. This open the regulating valve and admits more steam pressure t the cylinder, thus causing the speed of the engine to in-crease. This upward and downward motion of th weight is transferred by suitable mechanism, to the valv that governs the flow of the steam to the cylinder.

The Pendulum or Fly-Ball Governor.—This is th earliest and simplest form of the steam governor, bein based upon the application of the scientific principle a **revolving pendulum.**

In this governor, the centrifugal force is usual counteracted by the force of gravity, and acts upon th principle just described.

Construction.—A pair of heavy iron balls are ma to revolve about a spindle, which spindle is driven by th engine. Should the speed of the engine increase, th centrifugal force, as we have seen, also increases, and th balls tend to fly outward and upwards until the contro-ing or counteracting force is no longer able to hold the in their former circle, and as the balls move outwa they act on the regulating valve which **throttles** t steam, should it be a throttling engine; or, if an aut matic engine, this motion of the balls is made to cause **earlier** cut off of the steam in the stroke.

Effect.—The effect of this in the throttling engi is to decrease the steam **pressure** admitted to the ste chest, and thereby reduce the speed of the engi Should the engine be an automatic engine, such as Corliss engine, the effect is to cause an earlier cut which reduces the amount of steam admitted to cylinder, and thereby reducing the speed of the engi

Should the load on the engine be **increased**, then the steam pressure, or supply, must also be proportionately increased, and as the engine slows down the centrifugal force acting on the iron balls becomes less, causing them to drop and revolve in a smaller circle, thus opening the throttle valve wider and permitting a greater steam pressure, or, a **later** cut off, if an automatic engine. In **either** type of engine, the **speed** and **power** of the engine will be at once increased in proportion to the increased power supplied.

Advantages and Disadvantages.—The disadvantage of throttling the steam is the loss in **efficiency**, as fuel must be burned to keep up the boiler pressure, which at times is so throttled, or obstructed, that its **full force** can not be utilized, and is therefore wasted. This disadvantage is partly offset by the **decrease** in cylinder condensation.

With the variable or automatic cutoff engine, the steam is used continuously under almost full boiler pressure, the **supply** alone being regulated to meet the requirements of the engine. Therefore, the above disadvantage does not exist when this form of governor is used on an automatic engine.

In Fig. 158 is shown the usual form of a pendulum or fly-ball governor. The parts of this governor as indicated by the figures in the cut are as follows, viz.: 1, governor shaft; 2, standard; 3, governor balls; 4 stem swivel; 5, arms; 6, pivots; 7, pulley; 8, gear; 9, stem; 10, bonnet; 11, stuffing box; 12, glands; 13, valve discs; 14, valve seat; 15, stem guard; 16, valve chest flange.

In Fig. 177 is shown a more modern form of a **simple** pendulum governor, which form of governor is much used on Corliss engines. Instead of a single weight, two balls are used. These balls are suspended from a collar

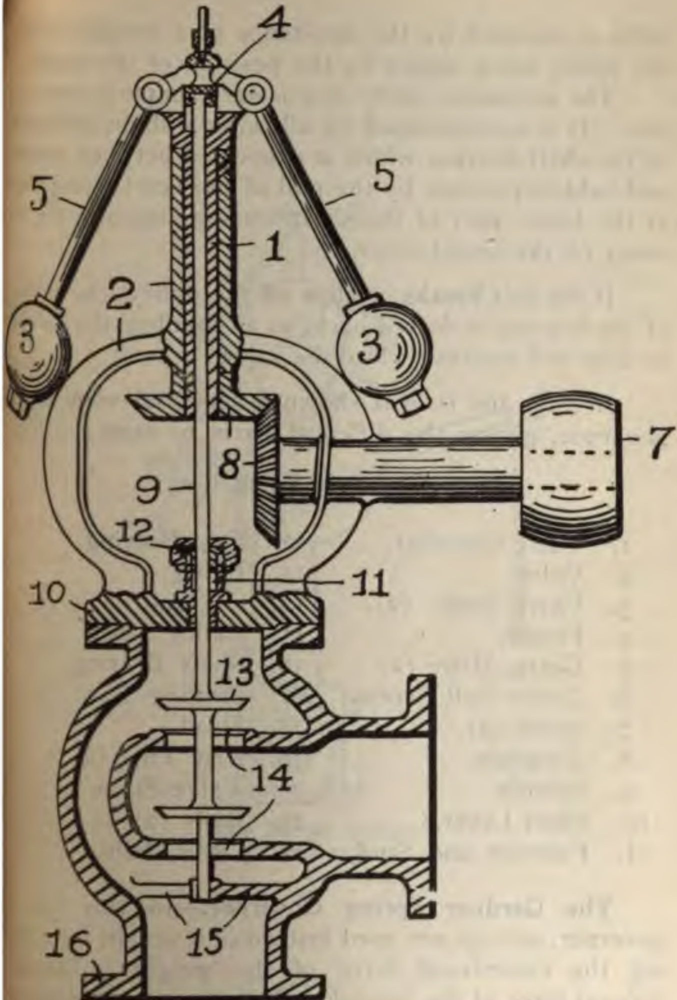
that is fastened to the spindle, and rotates with it. Links connect the arms to which the balls are attached, to a second collar that turns freely on a sleeve, not being attached to the spindle. The sleeve does not rotate, but is **free** to slide up and down on the spindle. When the balls fly outwards, the sleeve is pulled upwards by the links, this motion being transmitted to the valve gear by a connecting rod. To prevent **sudden fluctuations** of the governor, a rod which is connected to the sleeve, operates a piston loosely fitted in a cylinder, called a **dash pot,** which is filled with oil.

The Porter Governor.—This governor is a modification of a simple pendulum governor, whose **sensitiveness** has been much increased by adding to the **range of motion** of the centrifugal weights for a given range in speed. Fig. 159 shows the construction of this governor. The centrifugal weights 1.1 are **small,** and by running them at **high speed** their centrifugal force is comparatively great. In addition to their own weight, the balls must lift the large weight 2, that is made free to slide up and down on the spindle 3, this weight being lifted by means of the links 4.4, the weight 2 revolving with the spindle. At its lower end is attached a collar that gives motion to the lever 6. This lever transmits the motion to the gearing that operates the valve. 7 is a dash pot and 8 a small weight that gives additional adjustment. The governor is driven by a belt from a pulley on the engine shaft that drives the spindle 3, by means of the pulley 1.

THE GARDNER GOVERNOR.

In Fig. 160 is shown this old and standard form of governor. As here shown, it is a **gravity** governor having an automatic safety stop and speeder.

In action, the centrifugal force of the pendulous



Sectional View of a Throttle Governor.
Fig. 158

balls is opposed by the resistance of a weighte
the speed being varied by the position of the w

The automatic safety stop is very simple in c
tion. It is accomplished by allowing a slight os
of the shaft-bearing which is supported between
and held in position by the pull of the belt; a pr
at the lower part of the shaft-bearing supports
crum of the speed lever.

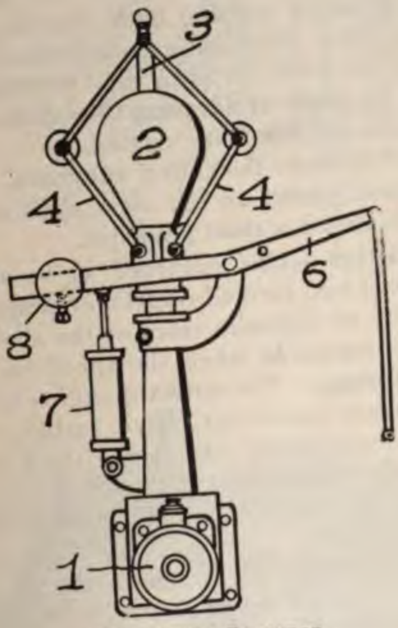
If the belt **breaks** or **slips off** the pulley, the
of the fulcrum is forced back, so as to allow the
to drop and instantly close the valve.

In Fig. 160 is also shown a sectional view
governor, giving the different parts of same.

Names of Parts.

1.	Valve Chamber.	12.	Step Bearing.
2.	Valve.	13.	Pulley.
3.	Valve Seats (2).	14.	Oil Cup.
4.	Frame.	15.	Pulley Shaft.
5.	Gears, Mitre (2)	16.	Shaft Bearing.
6.	Lever Ball Screw.	17.	Stuffing Box.
7.	Arms (2).	18.	Head.
8.	Toeplate.	19.	Arm Pins (2).
9.	Spindle.	20.	Valve Stem.
10.	Short Lever.	21.	Balls (2).
11.	Fulcrum and Stud.	22.	Lever Balls.

The Gardner Spring Governor.—In this t
governor, springs are used instead of a weight for
ing the centrifugal force of the weights. Th
trifugal force of the pendulous balls operates agai
resistance of this **coiled steel spring**, which is e
within a case and pivoted on the speed lever by m



The Porter Governor.
Fig. 159.

a screw. The amount of the compression of the spring can be changed so as to give a wide range of speed.

Shaft Governors.—As we have seen the power of an engine, and hence the work it performs can be regulated either by varying the point of cut off, or the point of compression, or by varying both of these points at the same time. One of the easiest methods of doing this is to shift the eccentric, so as to vary its throw and at the same time its angle of advance, thus making the engine a variable cut off automatic engine.

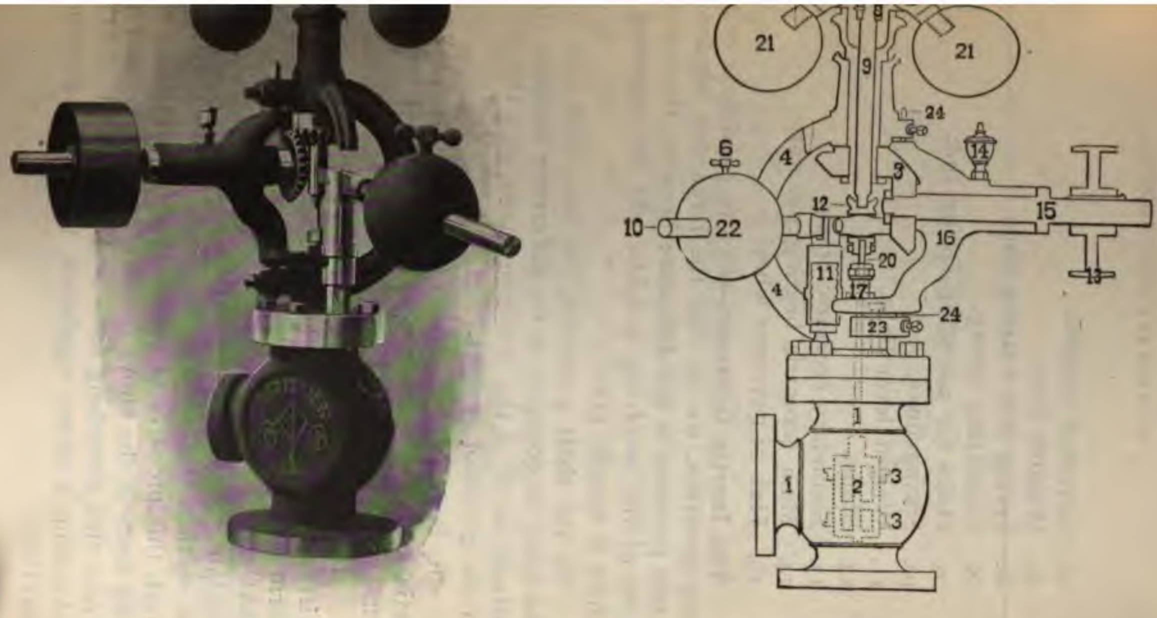
In order to make the cut off automatic, it is operated by a governor placed on the main shaft of the engine, and hence is called a shaft governor.

Construction.—This governor as usually constructed, consists of two pivoted masses, or weights, arranged symmetrically on opposite sides of the shaft; their tendency to fly outwards when the speed increases being resisted by springs. The outward motion of the weights closes the steam admission valve earlier, that is, decreases the steam supply, by making the point of cut off earlier, and the inward motion closes the valve later, that is, increases the steam supply by making the point of cut off later.

The steam supply is therefore effected by altering the position of the eccentric on the shaft, either by changing the throw of the eccentric, or of the angular advance.

Parts.—The following are the principal parts of an ordinary shaft governor for a high speed engine, the numbers corresponding with the parts shown in Fig. 161:

1. Rim of governor wheel.
2. Fly wheel arm.
3. Main eccentric.



The Gardner Governor, with Sectional View.
Fig. 160.

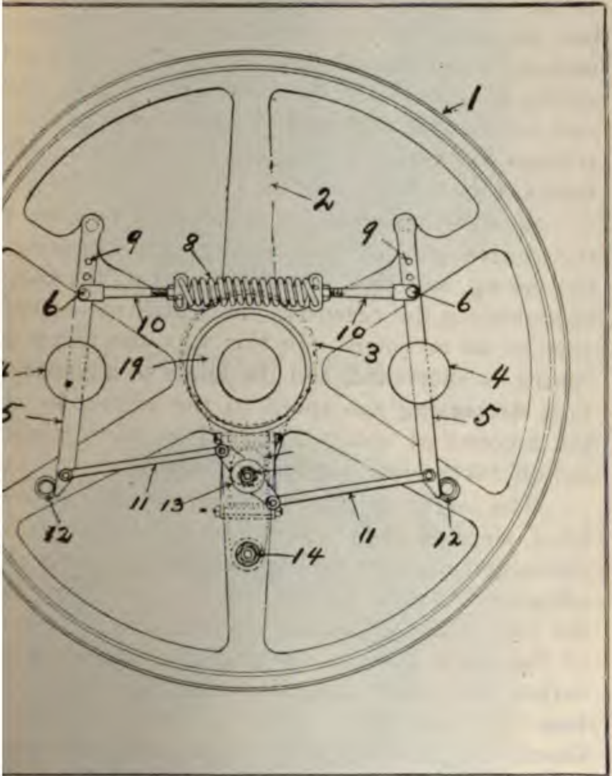
4. Governor weights.
5. Weights lever.
6. Spring link bearing pins.
8. Equalizing spring.
9. Holes for adjusting spring link.
10. Spring links.
11. Weight lever links.
12. Stops.
13. Secondary eccentric crank.
14. Main eccentric bearing pin nut.
19. Hub of governor wheel.

The Inertia Governor.—In the pendulum c tling governor, we see that the force that regul steam pressure is the **difference** between the ce force of the revolving weights, and the **opposi** which is usually gravity.

In the **shaft** governor, the force that acts the valve or eccentric is the **difference** between trifugal force of the revolving parts, and the r of the governor **springs.**

In both these forms of governors, the stat **ertia** has to be overcome, as it prevents to a ce tent very close or accurate regulation.

By **inertia** we mean that property of a virtue of which it **persists** in its state of rest o form motion in a straight line, unless some force that state. It is therefore a **resistance** to any c motion. As it takes some time and energy to pu in motion, and when in motion to bring it to a rest, this property of inertia therefore acts as a ing force in the above forms of governors; and come this disturbing force and make it an **assis** obtaining a closer regulation, the **inertia gover** devised.



a Shaft Governor for High Speed Horizontal Steam Engine.

Fig. 161.

Construction.—This form of governor cons of a wheel which is keyed to the engine shaft the sa as an ordinary fly wheel. Pivoted to this wheel i **bar,** the two ends of which are hollow. A spring is tached to one end of the bar, and the other end of spring is fastened to the rim of the wheel. One en this bar is **weighted,** and as the wheel revolves the trifugal force of the weighted end tends to carry it wards, this tendency being resisted by the spring.

Should the speed of the engine become **exces** the centrifugal force overcomes the opposing for the spring, and throws out the end of the bar, this tion shifting the eccentric pin, which pin serves the pose of an eccentric. In this way the throw of th centric is **shortened,** and the **angle of advance** incre thus **decreasing** the speed of the engine by decre the amount of steam admitted to the cylinder, a cut off takes place **earlier** in the stroke.

The inertia of this weighted bar acts as a regul force, since owing to its weight and length, it offers siderable resistance to any **sudden** change in the an advance, by allowing the wheel to advance **faster** the bar. This shifts the eccentric pin nearer the c of the shaft, thereby causing the cut off to take earlier, and preventing any great increase in spee **fore** the centrifugal force can act. On the cont should the load on the engine be suddenly **decrease** the same way regulation is maintained, for whil speed of the wheel is suddenly checked, the inertia o bar causes it to move **ahead** of the wheel, and so the eccentric as to make the cut off take place **late**

In Fig. 162 the form of inertia governor used o Junior engine is shown.

Construction of the Junior Inertia Governor.—

For Forward Running.

For Backward Running.

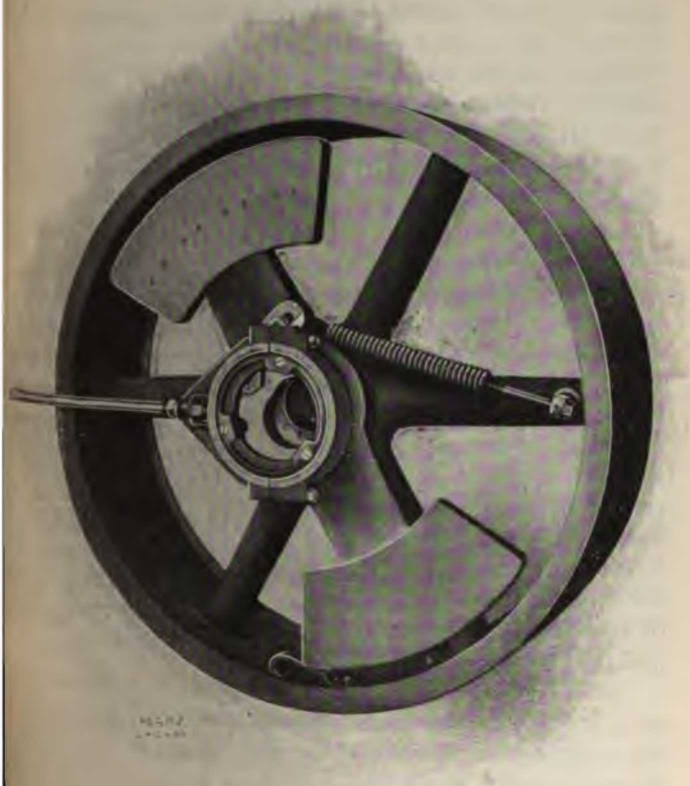
The Junior Reversible Inertia Governor.
Fig. 162.

governor, as shown in Fig. 162, is of the popular **"sin weight"** or **"inertia"** type, and is capable of giving tl ultra fine regulation generally regarded as such a va able feature in a steam engine. Aside from its exc lent speed regulating qualities, it is particularly attr tive on account of its simplicity. The governor wei is a simple casting of the form shown in the engravi on the preceding page. In this weight are screwed th steel pins 1. A small pin carrying a bronze roller, o which is hooked the end of the governor spring. 2. T spindle on which the weight swings. 3. A pin wit spherical head, which constitutes the eccentric.

The fly wheel serves as a carrier for the gover It has a bronze bushed hole through the hub, a little one side of the bore for the shaft, in which the spin on the weight is journaled. This is the only bear requiring lubrication, which is supplied by a compr sion grease cup. In suitable bosses in the arms of wheel are inserted two pins which limit the distance tl the weight can swing on its spindle. One of these p has a hole in it through which the spring tension scr passes.

The standard direction of rotation for Junior gines is such that when facing the nameplate the top the wheel runs toward the observer, and unless specia ordered to the contrary, governors are set to run in t direction. All Junior engine governors are, howe now so constructed that they can readily be set to in the **reverse direction.** The operation is exceedin simple, consisting in simply reversing the weights.

Combination Governor.—The requirements of modern engine are such that the speed must be ma tained practically **constant** through wide variations



The Brownell Combination Governor.
Fig. 163.

load, and this condition must be maintained whether th change occurs gradually or suddenly. A purely centr fugal governor will handle satisfactorily **gradual** chang in load, but cannot successfully take care of sudde changes; on the other hand a purely inertia governor ca care for **sudden** changes, but not gradual changes. T meet all conditions to which the modern engine is su jected, several makes of governors have in combinatic **both** the centrifugal and inertia elements.

Such a governor as shown in Fig. 163 is used the Brownell automatic engine.

Construction.—This governor consists essentially the usual single weighted arm, swinging on a pivot p Fastened to this arm is the eccentric that drives t valve. As the weight assumes different positions d to changes in load, the center of the eccentric is broug nearer to or farther from the shaft center, thereby reg lating the travel of the valve and the admission of t steam, in proportion to the work required. The ent absence in this governor of the usual complication links, dash pots, and other interlocking devices, togetl with its extreme sensitiveness, and the entire absen of any evidence of racing or surging commends it to practical steam users.

CHAPTER XVII.

VALVE GEARS.

Classification.—The **valve gear,** by which is meant the mechanism used to operate the valve, varies with the different types of engines. For a plain slide valve engine, this mechanism as we have seen, consists of the eccentric, the eccentric rod, rocker arm, valve stem, and the valve itself.

Should the engine be a type of the **reversible** engine, or a **variable** cut-off engine, the valve gear includes in addition to the above, the mechanism by which the motion of the valve is so governed as to change the **rotation** of the engine, or the **amount** of work done in the cylinder.

Fixed Cut-Off Gears.—In this type of gear, the motion of the valve does not vary with the amount of work to be done in the cylinder. Such gear is used on the plain slide valve engine, which has a **fixed** cut off, which cut off cannot be changed without changing the **construction** of the valve itself. When such gear is used, the points of admission, cut off, release and compression cannot be varied.

Variable Cut-Off Gears.—When the amount of work done in the cylinder can be regulated by varying the motion of the valve so as to change the point of cut off while the engine is in operation, the gear then used is designated as a variable cut-off gear. An **automatic** cut-off gear, in which the motion of the gear is controlled automatically by a governor, is called **an automatic variable** cut-off gear.

Reversing Gears.—When it becomes necessary that the direction of the rotation of the engine be constantly

[redacted]

changed, such as in hoisting work, a reversing gear must be used.

Types of Valves.—The leading types of valves are; slide valves, such as are generally used in slide valve, or variable cut-off engines; rotary valves, which are generally used on Corliss engines; and poppet valves, used only on slow and medium speed engines.

Of these types of valves, the poppet valves are less frequently used, their use being mostly confined to marine work.

Expansion Valves.—With a plain slide valve driven by a fixed eccentric, the range of the cut off is limited. With the "D" slide valve there cannot be an earlier cut off than one-half the stroke without interfering with the exhaust.

In order to extend the range of cut off, and at the same time not interfere with admission, release and compression, various types of auxiliary valves, known as expansion valves, have been designed for use in conjunction with the plain slide valve.

These auxiliary valves are driven by a separate eccentric, they being solely used to govern the admission of the steam without in any way interfering with the release and compression. With such an auxiliary valve the lap of the valve, or, the angle of advance may be changed as desired, without effecting the other parts in the steam distribution.

Therefore, this auxiliary valve, or riding valve as it is generally called, is alone used to vary the point of cut off.

The Meyer cut-off valve is a well known type of such expansion valve.

The Buckeye Valve Gear.—One of the best known applications of the riding cut-off valve, is the Buckeye

. In this gear the main valve is driven by the
e gear of a slide valve engine, making its op-
actly similar to that of an ordinary slide valve
ect rocker.

ut-off or auxiliary valve works inside of this
e, which is made either a hollow cylinder or
.

r. 185 is shown a sectional view of the cylinder
of the Buckeye engine, from which can be seen
ion of this riding cut-off valve.

ıain valve has two openings through the top
ct with similar openings in the steam chest.
n enters through these passages into the in-
he main valve. This valve has two openings
n the under side through which the steam is
the opposite ends of the cylinder when these
in line with the main steam ports.

am is exhausted past the outside edges of the
, it is therefore an indirect valve.

dmission of steam to the cylinder is regulated
off or riding cut-off valve, opening and closing
rts in the main valve. This permits the cut
aried through a much wider range than pos-
a single slide valve.

vantages.—While the disadvantage of the lim-
of cut off of the "D" slide valve is partly over-
he use of these expansion valves, there are
us objections to their use, all of which are
y the use of the Corliss valve gear.

ler to overcome the force required to drive
ry slide valve, due to the great pressure of
on the back of the valve, which not only
effects the action of the shaft governor, but
valve itself from the unavoidable wear from

the frictional resistance of the valve, many forms of so-called **balanced valves** have been produced.

Balanced Valves.—The most successful of these types of valves is the piston valve, heretofore described, which is a light and most perfectly balanced valve. A serious objection to this valve, and which has greatly restricted its use, is the **constant wear** of same. In horizontal engines especially, the weight ot the valve invariably wears the lower part of the valve seat, and thus destroys its circular form.

The **flat pressure plate valve** is a type which is also much used. A form of this valve is shown in Fig. 149.

For horizontal engines, the pressure plate valve possesses the advantage over the piston valve in that the wear of the valve which is on the **lower edge,** does not therefore effect the **tightness** of the valve.

The Corliss Valve Gear.—This form of valve gear was invented and first introduced by Geo. H. Corliss in the year 1848. It marked a new era in engine building. He first conceived the governor controlled cut off, and the easy moving valves, with their liberal exhaust ports which take care of both the exhaust and the condensation. It was Mr. Corliss who also first designed the proper engine frame, and made the engine self-contained.

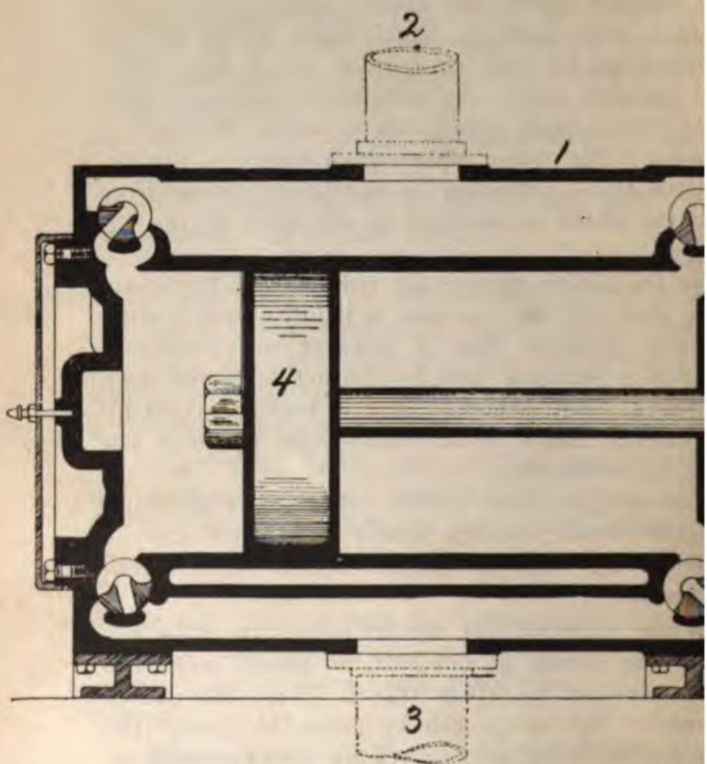
Construction.—In the Corliss gear there is a separate admission valve and a separate exhaust valve for each end of the cylinder, entirely independent of each other. The admission valves are operated by either one or more eccentrics, but they are automatically closed by dash pots or springs, when the piston reaches a designated point of its stroke. This point will vary with the position of the governor, which position will vary

:xhaust valves are cylindrical in shape, turn-
ndrical seats which extend across the ends of
er. The wrist plate which operates the ex-
es alone, receiving its oscillating motion from
ric which is fastened to the shaft of the en-

the piston reaches the point where the steam
shut off, the trip gear is held in such a posi-
he governor that it releases the admission
ch is snapped shut by the action of the dash
ring. The exhaust valve is made to open by
ndent action of the wrist plate which is op-
its eccentric.

dvantage of the Corliss valve gear is the long
he stroke through which the cut off can be
pending only on whether one or more eccen-
sed.

one eccentric, the cut off ranges from the be-
the stroke to one-half, at which point the
starts on its return travel. With the use of
trics this range can be extended almost the
ke, as the exhaust valves are then operated en-



Sectional View of Cylinder showing Corliss Valves.
Fig. 164.

: with the exhaust chamber and the exhaust he two upper valves are called the steam valves, two lower valves the exhaust valves. Each tends across the cylinder, making the length ilve about equal to the cylinder diameter. As n Fig. 164, the steam valves open their ports eir faces move away from the center of the towards the heads. The valves as shown in re single-ported, that is, they open but **one pas-** the flow of the steam to and from the cylinder, iese valves are often made **double-ported.**

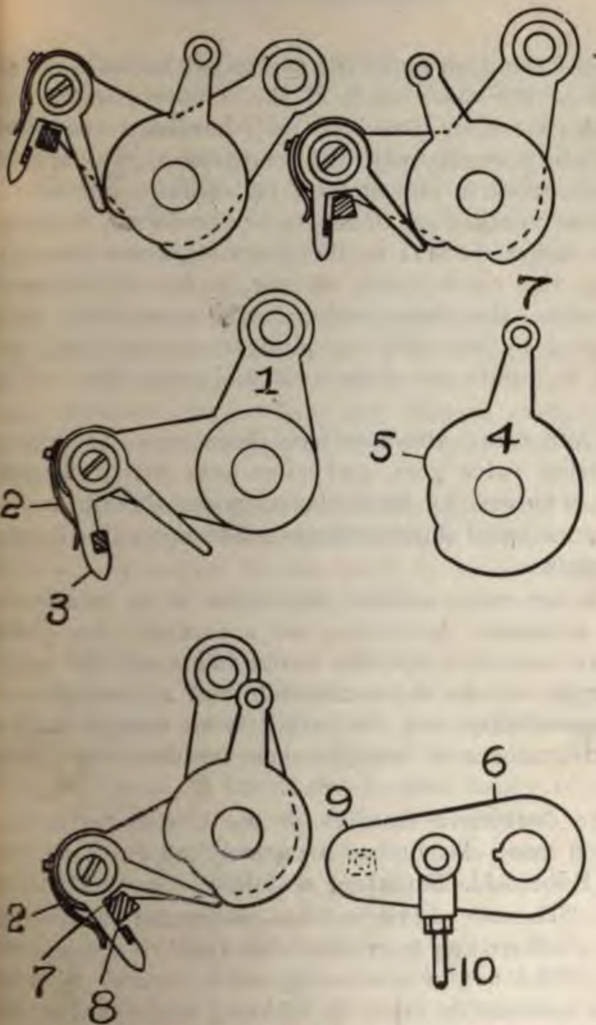
ianism for Operating Corliss Valves.—The m or gear employed to open and close the lve, embraces the most important features of valve gear. The principle on which the opera- l forms of Corliss gear is based is practically differing only in details of construction. The description will therefore make clear the Cor- gear as generally employed, reference being liagrams shown in Fig. 165.

he valve stem is placed a bell crank lever 1. d of the horizontal arm of this lever is a hook works freely on a stud. On the valve stem d next to the bell crank lever is a disc 4, which ed with a projection 5. This disc has an up- ctending arm 7 to which is connected one end f the rods from the governor. At the outer e valve stem is placed the valve stem crank 6, ries at its outer end the block 9, which is en- the hook 8, on the end of the bell crank lever. e crank stem 6 is connected to the rod 10 from pot. The operation of this mechanism may stood by referring to the drawing representing ent positions these parts occupy at the begin-

ning of the stroke of the piston. The disc 4, operat-
by the governor, is in a position to allow the hook 9 t
move to its highest position, or that position corre-
sponding to latest cut off, before being tripped by the
projection 5.

The hook has engaged the block on the valve stem crank or arm. Now, as the piston moves forward in the stroke, the bell crank lever is turned around on the stem by the rod from the wrist plate. The horizontal arm of the bell crank lever 1 carrying the hook 8, together with the arm on the valve stem, begins to rise and continues to do so until it arrives at the release position. The inner member of the hook follows the periphery of the disc 4, and is held in contact with the knock-off cam by the flat spring 2, which keeps the hook engaged with the block until reaching the projection on the cam. At this point the inner arm of the hook comes in contact with the projection on the disc 4 which forces the former further away from the center of the disc, thereby causing the hook to release the block carried by the arm on valve stem. The arm on the valve stem, being now disengaged from the hook is rapidly drawn downward by the dash pot and the rod 10, which causes the valve to close the steam port; thus effecting the cut off.

We therefore see that the essential parts of the Corliss valve gear consists of the following, viz.: (1) the steam valves; (2) the exhaust valves; (3) the double arm levers which work loosely on the hubs of the steam bonnets, and are connected to the wrist plates by rods (4) the wrist plate; (5) the connecting rods, between wrist plate and the double armed levers; (6) the levers which are keyed to the valve stem, and which are also connected by rods to the dash pot; (7) the dash p-



The Mechanism for Operating Corliss Valves.
Fig. 165.

[redacted]

rods; (8) the dash pots; (9) the steam hooks which are carried at the outer ends of the double armed levers, these hooks being provided with hardened steel catch plates which engage with the arms, making the arm and the hook work in unison until the steam is cut off. At this point another set of levers or cams (10), connected by the cam rods (11) to the governor, come into play causing the catch-plates on the hooks to release the valve arms, the outer ends of which are then pulled downward by the dash pot plunger, causing the steam valves to rotate on their axis and thus shut off the steam.

While many attempts have been made to improve the Corliss valve gear, and some have met with a fair degree of success for particular purposes, there have been but few material improvements made upon this form of valve gear.

No other valve admits the steam at so nearly full boiler pressure; determines so accurately the precise quantity necessary for the stroke; cuts off the supply so sharply; works the steam admitted so nearly to its full expansibility, nor discharges is so quickly with so little clearance and back pressure as does the Corliss valve.

The distinctive features of the Corliss valve gear has been most clearly and accurately set forth by Professor Robert H. Thurston, as follows:

1. "The use of four valves—two steam and two exhaust—so placed as to reduce 'clearance' to a minimum.

2. "The use of a rotating valve, capable of being cheaply and readily fitted up, of being easily moved, and of being conveniently worked by connections outside the steam spaces.

3. "The use of a 'wrist plate,' caused to oscillat

by a single eccentric, and directly so connected with all four valves that each may be given a rapid opening and closing movement, and be held open and nearly still, at either end of its range, by swinging the line of connection nearly into the line between centers, thus permitting nearly a full opening of port to be maintained during an appreciable interval, and a free and complete steam supply and exhaust.

4. "A beautifully simple and effective method of detaching the steam valve from the driving mechanism, and of insuring its rapid and certain closure at the proper moment, to produce any desired expansion of steam. (He is alluding to the dash pots and their attachments.)

5. "A direct connection of the governor, so as to determine the ratio of expansion, while so adjusting the power of the engine to the work to be done that the variation of speed with changing loads becomes a minimum.

6. "Making this latter adjustment in such a way as to throw the least possible work on the regulating mechanism, and thus to give the governor the greatest possible sensitiveness and accuracy of action.

7. "A form of frame and general design of engine which gives maximum strength and stiffness.

"All these features are combined to form a steam engine essentially different, in general and in detail, from all earlier engines. In operation the engine was found to exhibit a remarkable economy of fuel, and a singularly perfect regulation, and to be far more durable and more economical in cost of repairs, on the average than was generally supposed possible."

Adjustment of Corliss Valves.—The following instructions for making the proper adjustment of the

valves and gear of the Corliss engine are considered sufficiently general to answer for any Corliss valve gear and regulator.

Instructions.—Radial lines showing the opening or working edges or ports and valves will be found on the back bonnet of cylinder, and back end of valves as follows: For the steam ports, a mark on the cylinder coinciding with that edge of the port toward the end of the cylinder, a mark on the back end of valve coinciding with the edge of valve toward end of cylinder. The lap movement of the steam valve is toward that end of the cylinder in which the valve is located. The exhaust valve covers or works over the opening from the valve chamber into the exhaust chest, and the opening edge is that side of the opening toward the center line of the cylinder, and has its coinciding mark upon the cylinder. The mark on back end of exhaust valve shows its opening edge. The wrist plate is located central between the four ports on the front bonnet side of the cylinder, and has marks on the upper side of its hub showing the extremes of its travel and its center of motion.

To set the valves, place and hold the wrist plate on the center mark, or at the center of vibration and by adjusting threads for shortening and lengthening the valve connections, set the exhaust valve at the point of opening, and lap the steam valve from 1/8 to 3/8 of an inch, according to size of engine, the less amount for a 10-inch cylinder, and the larger amount for a 30-inch cylinder, and intermediate sizes in proportion. Now connect the wrist plate and eccentric rod and hook, and with the eccentric loose upon the shaft, roll it over and note if the wrist plate vibrates to the marks of extreme travel; adjust at the screw and socket in the eccentric

rod to make it vibrate to the marks. Now place the crank upon either dead center, and roll the eccentric enough more than a quarter of a revolution in advance of the crank, observing at this time in which direction it is desired to run the engine shaft, to show an opening of the steam valve nearest the piston of from 1/32 to ⅛ of an inch according to the speed the engine is to run.

This port opening at the dead center is commonly called lead, and is for the purpose of making an elastic cushion for the piston to rebound from or stop against. High-speed engines require more lead than slow-running engines, other things being equal.

Now tighten securely the set screws in the eccentric, and turn the engine shaft over in the direction desired to run it, and note if the other steam valve is set relatively the same, if not, adjust by shortening or lengthening its connection.

At a state of rest the weight of the regulator balls rests upon a pin in the side of the regulator column. To adjust the cam rods have the balls resting upon the stop-motion pin; then move and hold the wrist plate to one extreme of its throw, and adjust the cam rod for the steam valve, now wide open, so as to bring the steel cam on the cam collar in contact with the circular limb of the cut-off hook; move the wrist plate to the other extreme of throw, and adjust the other cam rod in the same manner.

To test the correctness of the cut off, block up the regulator to about its medium height, and, with the eccentric connected to wrist plate, roll the engine shaft very slowly in the direction it is to run; and when the cut-off hook is detached by the cam, stop and measure upon the guide the distance traveled by the cross head;

then continue the revolution of the shaft, and note whe the other steam valve is tripped; if cut off is equalized the distance traveled on the guides will be the same; not, adjust the cut-off rods until the points of cut off measure alike. The pin in the side of the regulator column, upon which the weight of balls rests, is to be removed when the engine is in motion and up to speed which allows the stop-motion cams to become operative and stop the engine in case of any breakage of the governor belt, which would allow the engine to run away unless thus guarded against.

To Adjust the Valves of the Reynolds Corliss Engine.—The working edges of the valves and ports are shown by radical lines on the ends of valves and valve chests, at the side of the cylinder opposite the wrist plate. Both steam and exhaust valves indicate lap when the lines on the valves are nearer the center of cylinder than the lines on the chests.

Fig. 182 shows wrist plate **central** for adjusting valve connections. Three marks on back hub of wris plate D and one mark on wrist plate stand, which i bolted to the cylinder show how eccentric connection i to be adjusted so that the wrist plate will travel correctly when in motion.

To set valves, place the center mark on wrist plat hub even with mark on wrist plate stand, and then adjust length of valve connections so the steam valves and exhaust valves B will have lap according to columns in table; the lap being given in parts of an inch opposite the size of cylinder.

Fig. 182 further shows position of wrist plate when the engine crank is on the center and eccentric se to give steam valves proper lead.

Exhaust valves will be correct if they have been s

ts shown in this figure, and will need no further atten- ion. Put crank on center and then move eccentric so hat steam valves will have lead according to table; the ad being given in parts of an inch opposite the size of ·linder.

TABLE FOR SETTING VALVES.

Diameter of Cylinder.	Lap of Steam Valves.	Lap of Exhaust Valves.	Lead of Steam Valves.
8	3/16	1/16	1/32
10	3/16	1/16	1/32
12	3/16	1/16	1/32
14	¼	⅛	1/32
16	¼	⅛	1/32
18	¼	⅛	1/32
20	¼	⅛	1/32
22	5/16	3/16	3/64
24	5/16	3/16	3/64
26	5/16	3/16	3/64
28	5/16	3/16	3/64
30	5/16	3/16	3/64
32	⅜	¼	1/16
34	⅜	¼	1/16
36	⅜	¼	1/16

Types of Corliss Engines.—There is no better way understand the operation of the Corliss valve gear an a study of the different types of the Corliss engines; d several of the leading types are here given, so that ery part not only of the valve gear may be fully un- rstood, but also its construction together with that of e engine.

Types.—Most of these different types of the Cor- ss gear may be divided into two general classes.

to the first class belong the **crab claw** gear, invented by Geo. H. Corliss, and still used by many Corliss engine builders.

To the second class belong the **half moon** valve gear, as used on the Reynolds-Corliss engine, and which is followed in more recent designs of Corliss engines.

Description.—In the first class, or the old style crab claw gear, the valve opens **towards** the center of the steam cylinder, which **obstructs** the passage of the steam supply, as it forces the steam to pass over and around the valve.

In the second class, or the Reynolds-Corliss valve gear, the steam valve is made to open **away** or **from** the center of the cylinder, thus leaving a clear and direct passage for the steam into the cylinder.

The Corliss valve gear is called a **detachable valve gear** because the valve is opened **positively** at the proper time by the direct action of the working parts of the engine, and continues to open until closed by the detaching or tripping of the hook, which is operated by the action of the cut-off cam. This time, or point, in the stroke at which the tripping takes place is determined by the **position** of the cut-off cams, which are operated and controlled by the governor. This point of cut off is therefore determined by the requirements of the load on the engine.

Construction of Corliss Valve Gear.—The Corliss valve gear and connections are so constructed and arranged that adjustment can be made while the engine is in **motion,** which is not only a great convenience, but facilitates the setting of the valves by the aid of the indicator.

Dash Pots.—Vacuum dash pots are employed on nearly all engines, being fitted with improved regulat-

which insure a high and uniform vacuum,
r the dash pot absolutely noiseless in opera-

nors.—The governors employed on Corliss
e of two types, viz.: the ordinary fly ball or
governor, and the weighted or Porter type
r.

Motion.—All Corliss governors are provided
motion, which causes the engine to stop im-
upon the failure of the governor itself, or the
r slipping of the governor belt off the pulley.

sing Valve Gear.—For ordinary stationary
nes are made to rotate in one direction only,
g no necessity to reverse the engine. As we
should it be desired to reverse the direction of
the ordinary slide valve engine, the eccentric
oosened on the shaft and rolled over, so as
a position exactly opposite to its former posi-
e shaft.

l the engine have a shaft governor, the
springs must be changed over, so as to act
site direction from what they did in order to
e direction of the rotation of the engine.

these types of engines can be reversed in
r indicated, the ratio of expansion continues
hat is, the cut off continues to occur at the
t in the stroke.

ne engines the character of the work requires
to be frequently and quickly reversed, and
oint of the cut off altered, such as locomo-
ine and hoisting engines, where not only the
e engine constantly varies, but also the direc-
ich the engine must be run.

es designed for such work must therefore be

provided with certain mechanism that will enable th engineer not only to **reverse** the engine with ease, bu also **alter** the ratio of expansion.

Where the work is heavy on the start, as a loco motive pulling a train, suitable means must be provided to give a **late** cut off; and as the work becomes lighte from the train being in motion, the cut off must be made **earlier,** so as to use less steam and allow more for its expansion.

With only **one** eccentric, this cannot be done, as the **motion** of the valve cannot be reversed so as to not only change the admission and exhaust ports, but also alter the point of cut off, without **resetting** the entire valve gear.

Now, instead of having only one eccentric, if two eccentrics are used, it will permit the motion of the valve to be quickly reversed, and will also allow the point of cut off to be varied, by disconnecting the valv from the first eccentric and connecting it to the secon eccentric.

For instance, should the right hand port be opene for admission and the left hand port to the exhaus then to **reverse** the engine the **travel** of the valve mu be reversed, so that the left hand port is open for ad mission and the right hand port to the exhaust.

In this way the engine can be worked with ease **either** direction, and the point of cut off varied wi the requirements of the load on the engine. There a two principal types of reversing gear, viz.: **link motio** and **radial gears.**

The Stephenson Link Motion.—One of the earlie and most common arrangements for reversing engin and changing the ratio of expansion, is the Stephens Link Motion, illustrated in Fig. 183. The two ecce

trics 1 and 2, whose centers are 3 and 4 respectively, are keyed to the crank shaft of the engine. The two eccentric rods 5 and 6 are connected to the slotted link 11. This link is suspended from the point 13 by the system of levers. The block 14 fits the link, and slides in it when the link is raised or lowered, which is done by moving the lever 7, which raises the link by means of the bell crank lever 8 and the rod 9. The block 14 travels back and forth from 10 to 12, according to the position of the lever 7. The block 14 is directly connected to the valve spindle, which drives the valve 15.

This link motion, therefore, consists of two eccentrics and eccentric rods, and a slotted link.

In this form of link motion, the two eccentrics must be placed on the shaft in such a way that if the valve is operated by one of the eccentrics, the engine will move **forward**, and if by the other eccentric, it will move **backward**. When the block is at the end of the link **nearest** the forward eccentric, the engine will move forward; when the block is at the other end of the link, the engine will then move backward.

As the block is moved nearer an **intermediate** position, the travel of the valve becomes **less**, and consequently the cut off becomes **earlier**. When the block is in a **central** position of the link, the travel of the valve is not enough to uncover the ports, and therefore the engine remains **at rest**.

Where the engine is direct connected, we have seen that the eccentric radius must be 90 degrees plus the angle of advance ahead of the crank. To make the engine run in the opposition direction, it is only necessary to **reverse** the eccentric radius so that it will still lead the crank by 90 degrees plus the angle of advance.

This is the principle upon which all reversing valve gear is constructed.

The Gooch Link.—With this gear the link is not raised or lowered, but remains **stationary.** The radius of curvature of the link is made equal to the length of the radius rod. This permits the block to be moved from one extremity of the link to the other, without moving the valve. Therefore, the lead must be **constant** for all points of cut off.

Reverse Valve.—The use of two eccentrics can be dispensed with to reverse the motion of engines by using what is known as a **reverse valve,** such as used to reverse the motion of elevator engines, and which will be described in a later chapter.

Radial Gears.—This is a type of valve gears that perform nearly the same functions as the link motions above described. In these gears the motion imparted to the valve may be varied so that the point of cut off or the direction of rotation, or both, may be readily changed. These valve gears are expensive and difficult to keep in good repair, and are therefore not generally used.

The Joy Valve Gear.—This valve gear is a **radial** valve gear, and is applied to vertical reversing engines. With this gear no eccentric is used, but motion is imparted to the valve by the motion of a connecting rod.

Gridiron Valves.—With this form of valve, a **liberal port opening** can be obtained with a **short range** of travel, thus reducing the wear of the valve and seat and thereby the power required to operate the valve.

The **disadvantage** in the use of this valve is the resistance to the flow of steam through the narrow passages between the bars, thus causing the steam to be **wire drawn.** This objection can be partly overcome by

the use of a sufficiently **large number** of bars, so that the aggregate area of the openings can be made sufficiently large.

Arrangement of these Valves and Valve Gears.—The general arrangement of the Gridiron valve and gear can best be understood by describing those of the McIntosh-Semour engine, as shown in Fig. 184.

ST. LOUIS CORLISS ENGINE.

In Fig. 165 is shown a back view of the girder frame type of this engine.

Valve Gear.—The valve gear shown in Fig. 166 is the standard hook releasing type, operated by eccentric on engine shaft; the releasing devices on the steam valves are controlled automatically by action of the governor, and the regulation of the engine is held within 2 per cent under all changes of load within the full capacity of the engine.

The valves are circular, and carefully fitted to the chambers; the valve stems are made from forged steel.

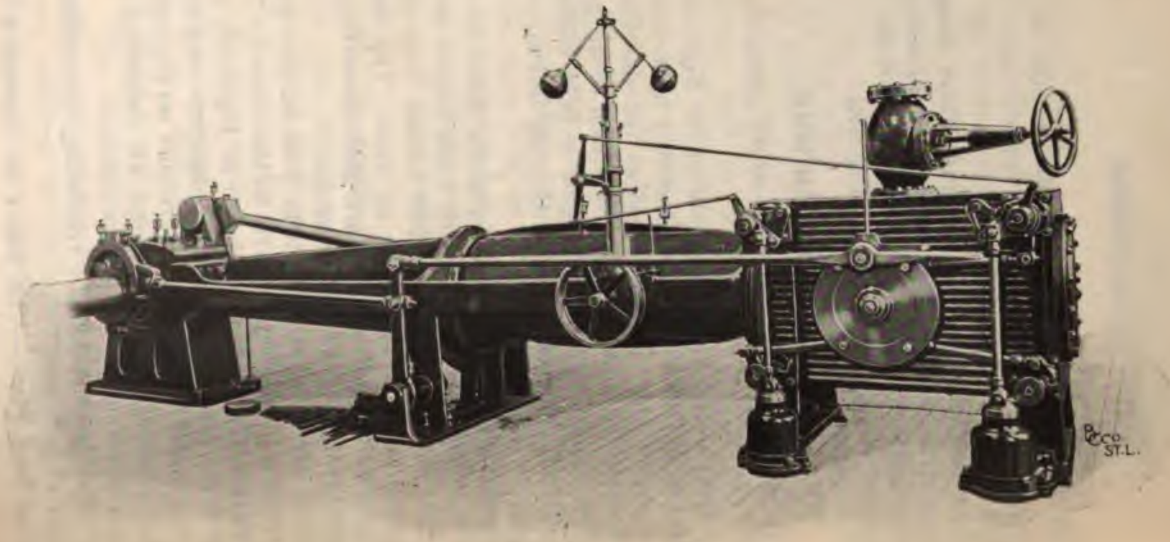
All valve rods are provided with bronze stub ends having adjustable boxes for taking up wear. The valve hooks are also of bronze; all pins are made from forged crucible steel, ground and fitted to gauge.

The wrist plate is circular, with pins located near the circumference giving rapid travel to the valves.

Dash Pots.—The dash pots shown in Figs. 166 and 167 are of the vacuum type, with plungers enclosed, silent and dust proof, self-contained, require no pipe connections, are positive in action under all variations of load or steam pressure.

An air valve is provided for regulating the cushion of the plunger chamber.

Frame or Bed Plate.—The frame as illustrated in



The St. Louis Corliss Engine.
Fig. 166.

[redacted]

Fig. 166 is the standard girder type, with heavy backbone directly in the line of strain, with stiffening ribs at the end of the guides which effectually prevents the guides from springing or opening, whether engine runs under or over.

Cylinder.—The cylinder shown in Fig. 167 is made with heavy walls and strongly ribbed, making it safe to carry high steam pressure.

The cylinder is made from a special clear, close grained iron, very strong; with this iron, after being a short time in use, with good lubrication, a glaze is formed in cylinder, making the wear very slight.

Condensation is almost entirely prevented in the cylinder by providing a dead air space between the exhaust steam passage and the bore of the cylinder; the cylinder is surrounded with mineral wool, and covering the entire cylinder is a cast iron jacket of neat design.

Cross Head.—The cross head shown in Fig. 168 is made with taper adjustable shoes, each lined with best anti-friction metal.

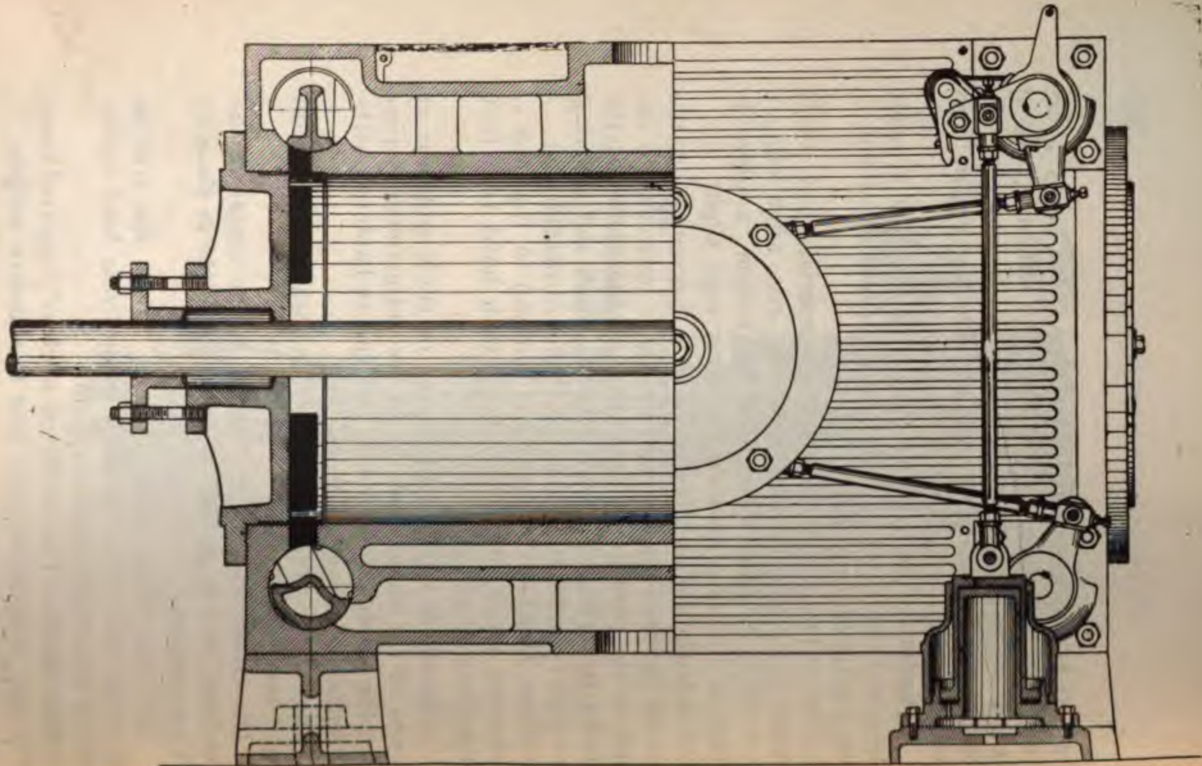
Adjustment is made by means of studs and nuts at the end of the shoes, and the closest adjustment is possible; the shoes can be taken out and re-babbited without removing the cross head.

The shoes are fitted to cross head tightly with tongue and groove.

The cross head pin is located in the center of the cross head, and is ground to a taper fit, held in place by two cap screws.

The cross head is threaded to receive the crucible steel piston rod, which is fitted to the cross head tightly and held from turning by jamb nut.

Main Shaft.—The shafts are made of faggotted hammered iron, turned perfectly true to standard gauges.



St. Louis Corliss Cylinder

[redacted]

Piston.—As the piston and its connections have to :ceive all the pressure of the steam, being enclosed in ıe cylinder, where it can only be examined at an ex- :nse of time and labor, it is absolutely imperative that shall not only be extra strong, but safe.

The piston as seen from Fig. 169 is made in three ırts, viz.: the head, follower and bull ring. The piston ›d is ground to gauge and the piston shrunk on, keyed ıd riveted, making it an utter impossibility to become ose.

The bull ring is provided with sectional packing ng, kept positively steam tight by means of bronze ·epers, held in place by non-corroding coil springs.

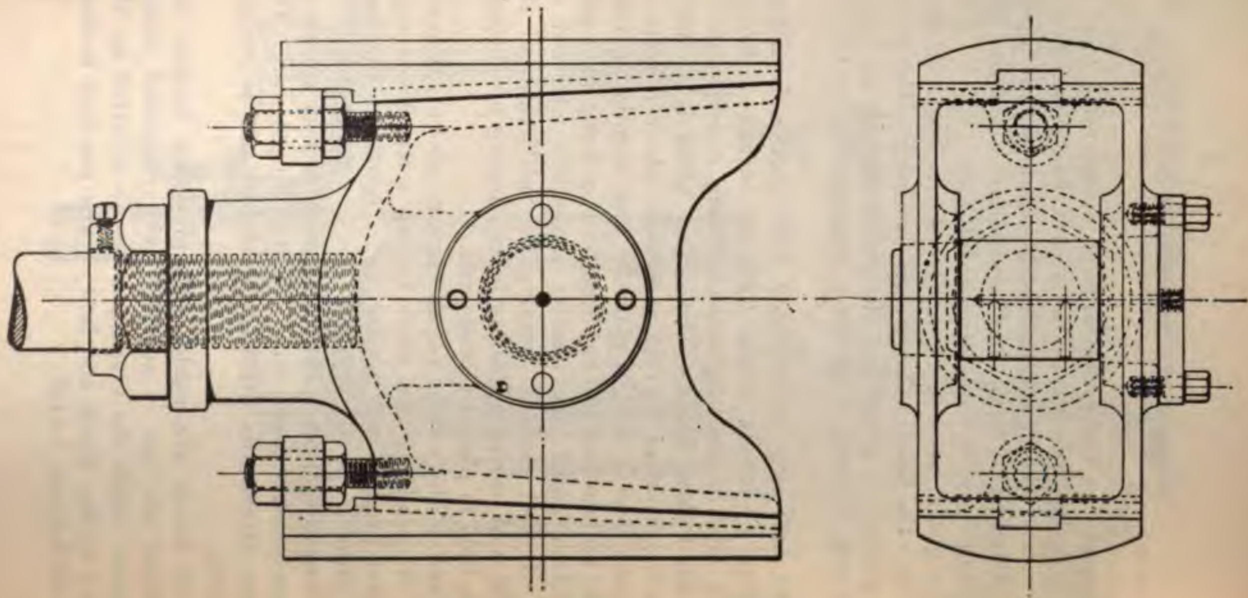
Main Pillow Block.—The pillow block is of heavy :sign, has a broad bearing at bottom where it rests on undation, and is held in place by four foundation rods.

The bottom box and two quarter boxes are lined with ıti-friction metal, the quarter boxes are adjusted by eans of steel wedges, running the full length of the urnals, and having adjusting bolts running up through ıe cap, held in place by jamb nuts.

Crank.—The cranks on all engines above 175 horse ɔwer are made of cast steel, having a tensile strength f 60,000 pounds per square inch, equal to the best ɔrged iron.

Connecting Rod.—The connecting rod as shown in 'ig. 170 is made solid, from selected forged iron. The :nds are afterwards drilled and slotted out to receive the boxes.

Both boxes are made from phosphor bronze, the cross head pin box is adjusted with improved wedge adjustment, while the crank pin box is adjusted by the standard wedge block and bolt; crank pin box is lined with anti-friction metal.



St. Louis Corliss Cross Head.
Fig. 168.

Governor.—The governor is the standard automatic centrifugal ball type, driven by belt from engine shaft.

It is slow speed with heavy balls, giving the closest egulation possible to obtain.

The balls are quick to act whenever there is a hange of load on the engine, and the regulation is even nd prompt, whether the load is suddenly thrown on or ff, or the steam pressure changed.

The governor is fitted with an automatic safety top which shuts down the engine should an accident ccur.

It is also provided with an oil dash pot to prevent hasing of engine and a weighted lever to change speed.

Wheels.—The iron used in the manufacture of the heels is clear selected pig, free from impurities and elected for its strength.

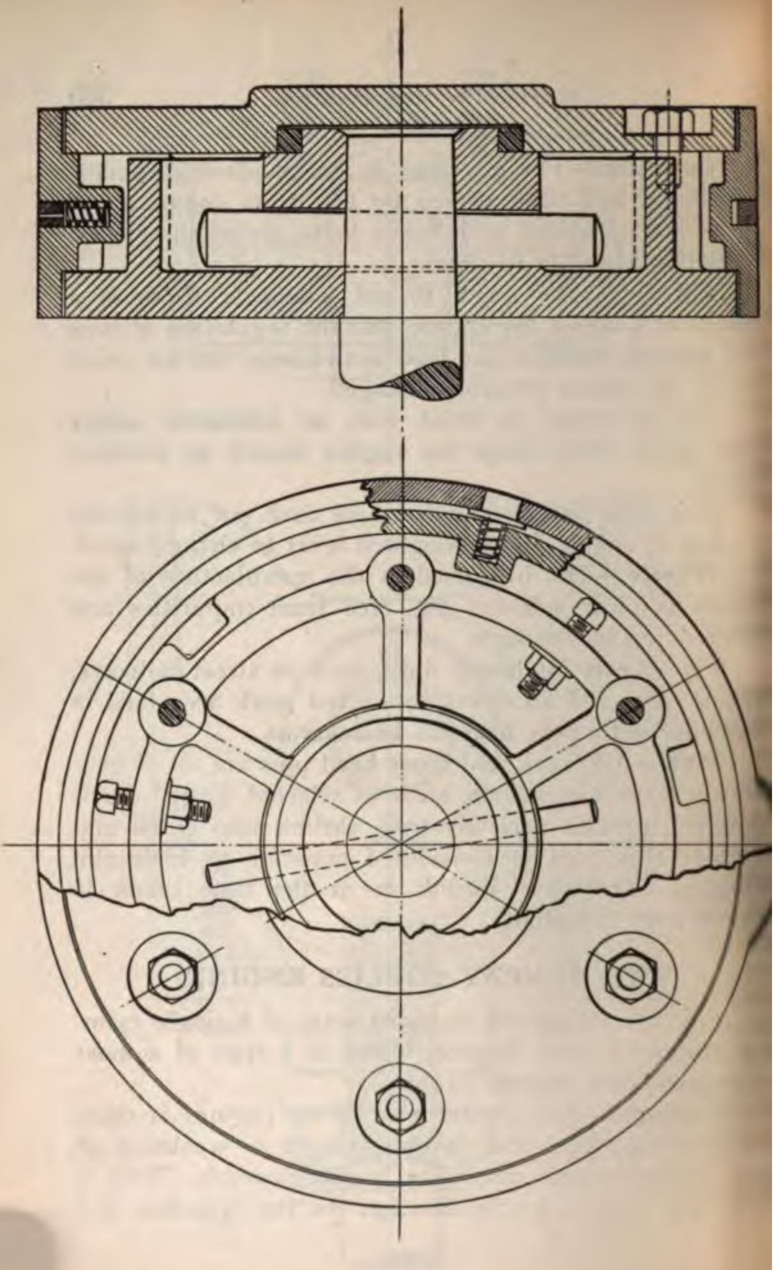
Fly wheels for heavy duty, such as street railways, olling mills and all direct connected work are made in egments with very heavy I beam arms.

Pins.—All crank and cross head pins are all of genrously large dimensions, made of selected, forged crucile steel, ground perfectly true, shrunk into crank and iveted; this plan is considered superior to hydraulic pressing. They are shrunk in at the time crank is shrunk onto the shaft.

THE MURRAY CORLISS ENGINE.

Fig. 171 shows the standard form of a single cylinder Murray Corliss Engine, which is a type of a most economical and efficient engine.

Castings.—The greater part of all engines is composed of cast iron, and on the strength or weakness of such castings, their durability largely depends. This is especially true as to the castings for the cylinders and



ly wheels, and the builders of this engine have given his most important feature especial attention.

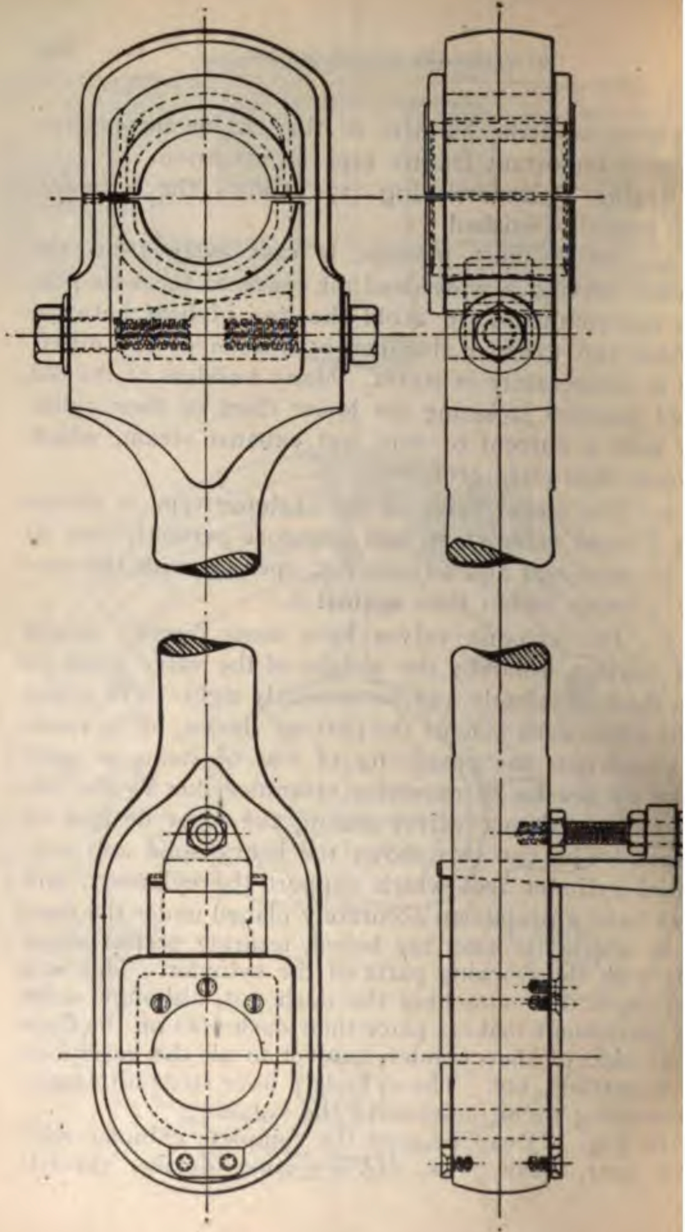
Engine Cylinders.—Fig. 172 shows the cylinder, when partially finished.

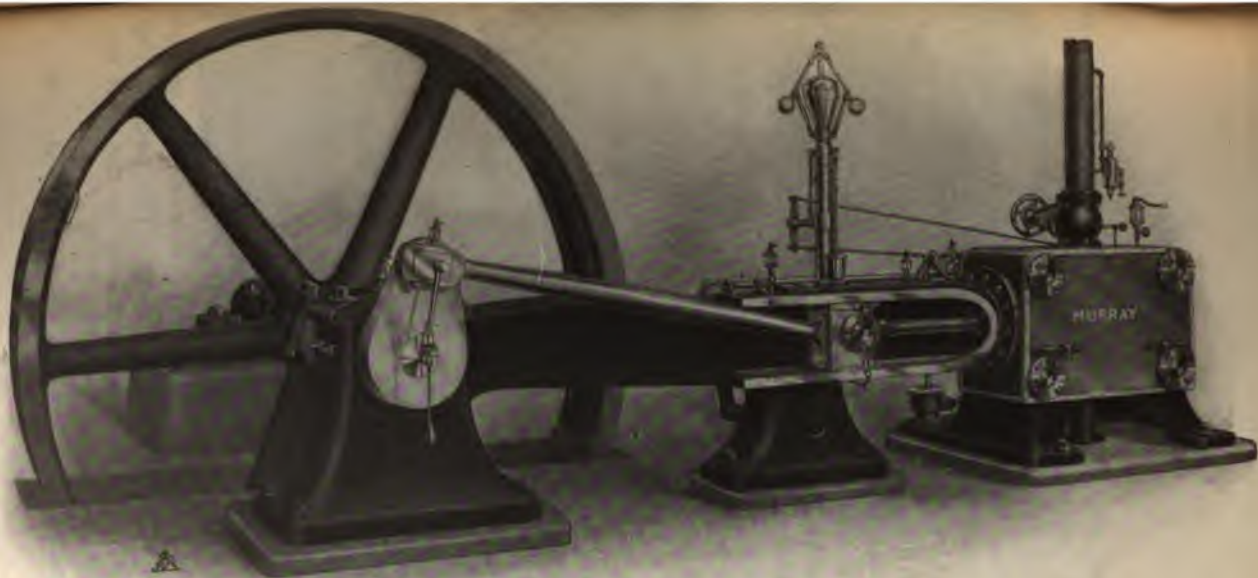
1. The exhaust passage is cast **away** from the cylinder, leaving a wide dead air space as the best possible non-conductor, to avoid the loss of heat between cylinder and exhaust chamber by reason of the difference in temperature in steam. Many builders of the old school practice jacketing the lower third of their cylinders with a current of cold wet exhaust steam, which prevents first-class economy.

2. The steam valve of the skeleton type is driven by a T-head valve stem, and therefore perfectly free to find its own seat and adjustment, opening **with** the current of steam rather than **against** it.

3. The exhaust valves have seats directly below their centers, whereby the weight of the valve tends to keep them absolutely and permanently tight. The space in the valve each side of the port, as shown, being made solid, prevents the possibility of loss of steam at each stroke by reason of excessive clearance due to the use of skeleton exhaust valves among the older designs of engines. The cut also shows the heavy solid and substantial cylinder feet which support the cylinders, and which have a projection accurately planed under the dash pot to which the latter are bolted, insuring perfect alignment with the working parts of the cylinder. This is a good method of attaching the dash pot, although some very prominent makers place their dash pots on the floor at one side of the cylinder, subject to all the variations due to settling, etc. The cylinders have large air spaces surrounding them underneath the lagging.

In Fig. 173 can be seen the complete cylinder with valve gear, dash pots, disconnecting device, throttle





The Murray Corliss Engine.
Fig. 171.

valve, etc., also showing the cylinder feet, which are **extended** to receive the dash pots.

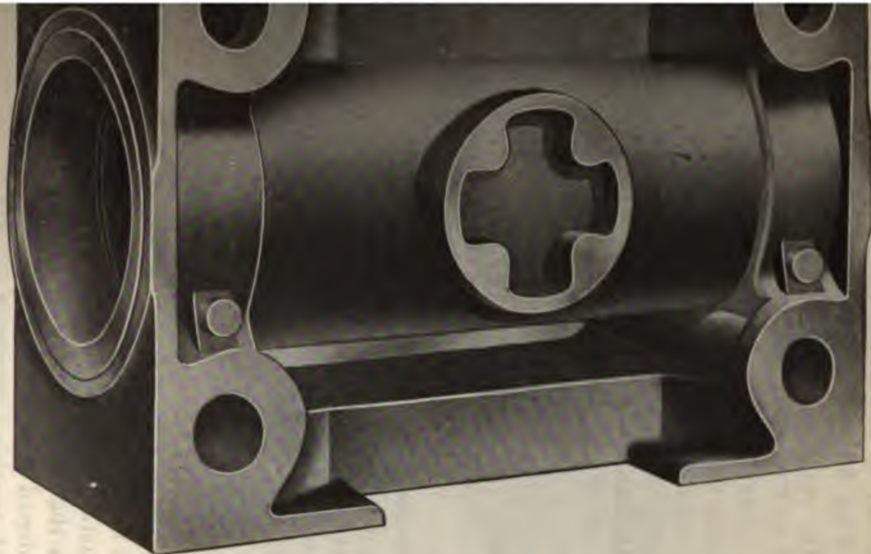
In Fig. 174 is shown the **course** of the steam through the valves. As seen from Fig. 174, the exhaust passages are cast away from the cylinder, leaving a wide dead air space, which is the best of all non-conductors. The course of the live steam is kept away from the cold wet exhaust steam.

Valve Gearing.—Fig. 175 shows the **simplicity** of this releasing gear. The knock-off lever is fitted with **double cams** for use with an automatic safety stop motion, which causes the engine to stop should the governor belt break, or the governor be stopped by accident. The **catch** plates are made of hardened steel, and each has eight wearing edges.

Dash Pots.—This style of dash pot is faced on the bottom, and is bolted to a part of the cylinder foot, which extends to receive it, and which is faced off for it. The adjusting valve is made a part of the dash pot. The plunger has no nuts or screws in the bottom to cause clearance and consequent loss of vacuum, or to get loose and come off or drop into the pot and cause accidents. The lower end of the drop rod is connected to the plunger by a ball and socket joint, with convenient means for taking up the wear; this allows it to be adjusted for length much more conveniently than otherwise, and without the possibility of cramping the rod or plunger.

Piston.—Fig. 176 shows the **solid** piston without follower bolts, which is used with this engine. It is a very simple piston, as it has no follower bolts or studs to come loose or require adjusting. The **packing rings** are made so as to provide for taking up the wear **automatically,** thus remaining tight.

The pistons are pressed on to the rods with hy-



A Partially Finished Corliss Cylinder Casting.
Fig. 172.

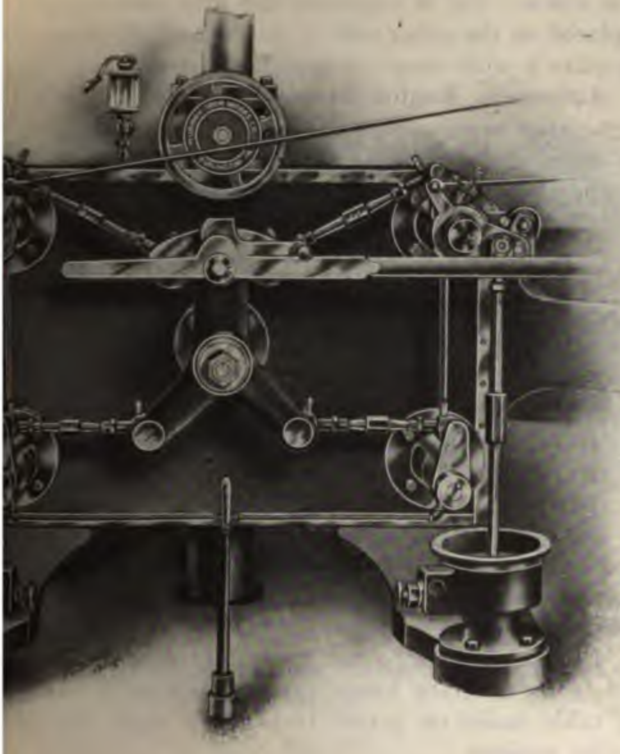
draulic pressure and locked with a special st which nut is also locked; then the piston and turned up, finished and polished together.

The rings used are sectional or eccentric as t speed and working pressure of the engine make able. They are fitted to the pistons by hand an sectional packing rings are used, the joint and clips are made of bronze and the coil springs of steel.

Governor.—At the present day when every n is worked at its maximum speed, and electric chinery is so frequently driven directly from the motor, close regulation is a most important matt no one can afford to overlook it or under-rate i close regulation of this engine has been obtained use of a **high speed governor, making from two t revolutions to one of the engine,** whereas in the designs of slow speed engines the governor usuall about one revolution per revolution of the engine Consequently this governor is able to act four times more quickly than any of the older styles it is also more powerful and has less friction and ance to overcome.

Fig. 177 shows the detail construction of this nor. It will be observed that the center weight iron has a cavity in the top to receive shot or a spr adjusting the speed even to a fraction of a revo also that all the vertical thrust bearings are fitt hardened steel balls which produce a light runni most sensitive governor.

Special Attachment to Governor.—In order just the speed while the engine is **running,** a spe tachment to governor is used on this engine, co of an **adjustable weight,** as shown in the cu



A Complete Corliss Cylinder,
g Valve Gear, Dash Pots, Disconnecting Device, Throttle
Valve, Etc., of Murray Corliss Engine.
Fig. 173.

weight may be moved in or out on the rod and fast by a screw. Or, if required, the arm and weight be placed on the other side of the belt crank, thus obt ing quite a wide range of speed adjustment.

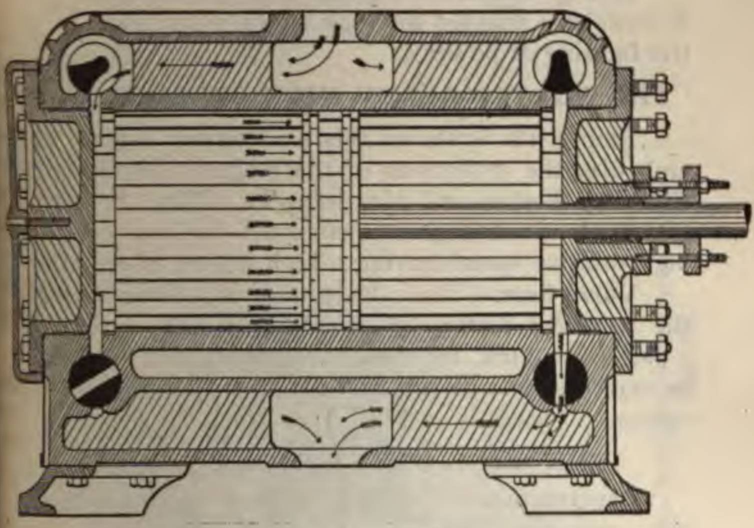
Automatic Engine Stop.—Fig. 178 illustrates engine stop used on this engine that automatically s the engine by shutting off the supply of steam in the engine speed either exceeds or falls below the sp desired, also if the governor belt breaks or the gover ceases to revolve from any cause. The valve is pl just on top of the throttle valve and the valve and gearing are the same as the steam inlet valves of cylinder except that the valve and port are shorter wider and that its closure is accomplished by mean a spring or weight in place of a dash pot. The kn off cam is operated by a rod attached to a bell crank the governor.

This stop is capable of very delicate adjustment the valve and valve stem being made of bronze the no danger of its becoming corroded and sticking. stop is operated by a separate governor when used cross compound engine as shown in the cut.

Economy.—The great economy of the Corliss gine in its different forms can be seen from the fol ing table based on actual tests made with the Mu Corliss engines.

HORSE POWER OF STEAM BOILERS WI DIFFERENT ENGINES.

Size of Boiler	42 x 12	48 x 12	48 x 16	66 x 16	7
Ordinary Engine	30	45	60	105	
Simple Corliss, Non-Condensing	41	61	82	144	
Simple Corliss, Condensing	53	80	107	187	
Compound Corliss, Condensing	68	100	135	237	



Vertical Section Through Corliss Cylinder, Showing Course of the Steam.

Fig. 174.

THE HAMILTON CORLISS ENGINE.

In Fig. 179 is shown this make of a **high spee** liss engine.

THE HARRISBURG FOUR-VALVE ENGI

In Fig. 180 is shown this four-valve engine, is especially adapted for high speed work, such a tric lighting or power.

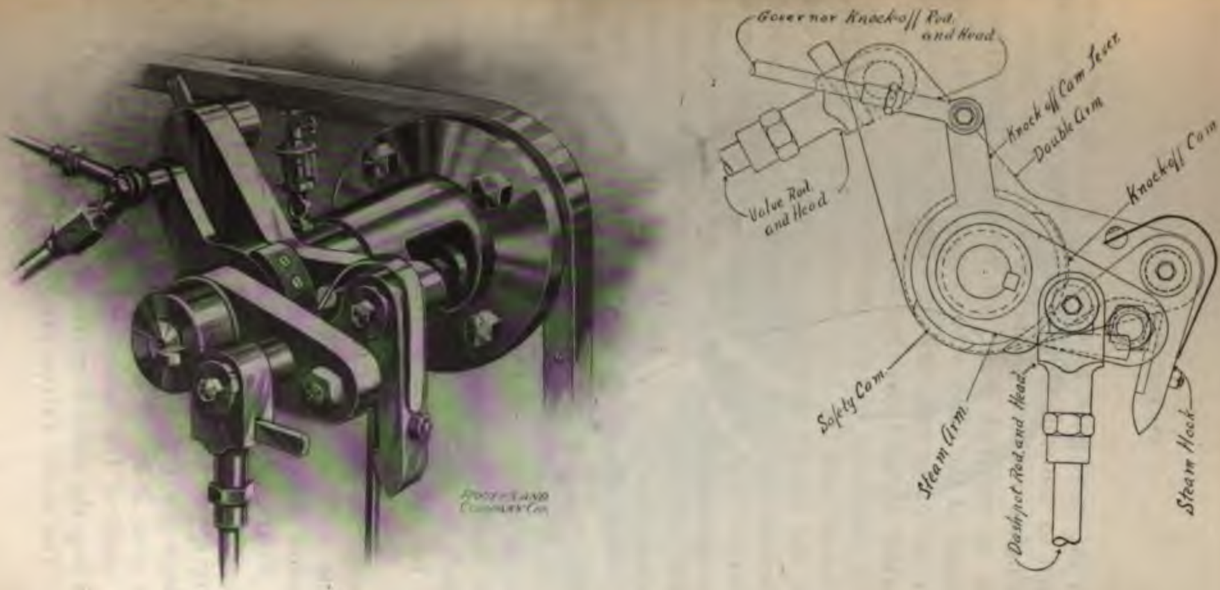
THE PORTER-ALLEN HIGH SPEED ENGI

In Fig. 181 is shown this well known engine, embodies the inventions of the eminent engineer Chas. T. Porter and Mr. John F. Allen. It w first high speed engine constructed for heavy w high rotative speed, having a high degree of econo

Valve Gear.—The valve gear is of a distinctive the principal feature of which is a **link,** actuat a single eccentric, from which **separate** and **indepe** movements are given to the admission and e valves.

THE McINTOSH-SEYMOUR ENGINE.

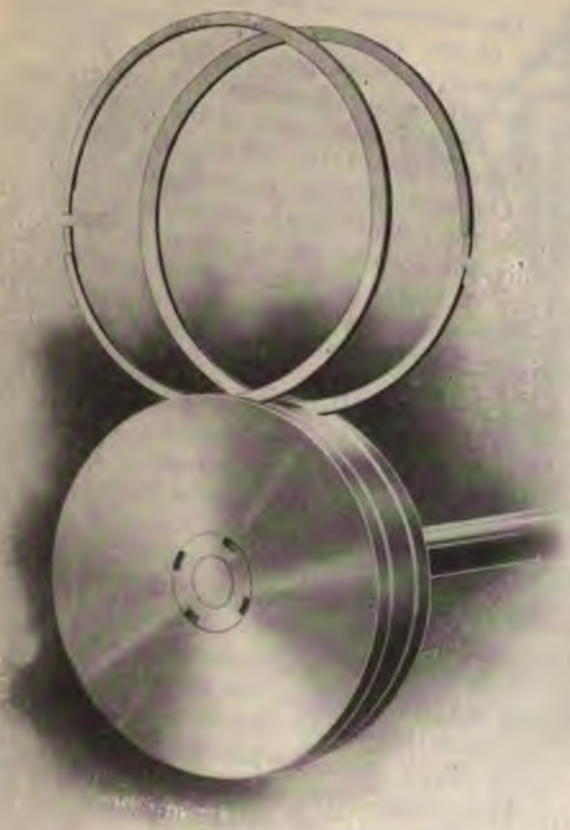
Construction.—The flat Gridiron valve of th gine, as shown in Fig. 184, is clearly seen. valves are unbalanced, and the port edges are ranged so as to be wide open without forming shou The steam valves are free to lift, which gives addi security against damage from water in the cyl The valve seats are separate from the cylinder an fitted with scraped joints, so as to be steam tight out packing. Both valves and seats are scraped t face plates, and have their port edges, as well and wipe-over grooves, accurately machined. valves require much less waste or clearance space with Corliss valves, where the cylinder dimension port areas are the same.



The Murray Corliss Valve Gearing.
Fig. 175.

In the valve gear, as shown in Fig. 184, links, which are used to transmit motion to the valves, are actuated by swinging rockers in such a way as to distort the motion as received from the eccentric, hastening the movement of the valve when near one end of its stroke, and at the other end causing a pause in its motion, so that while a rapid opening and closing of the port is secured, the valve remains practically still while closed. This feature and the large number of ports in the valve reduce the stroke necessary to give full port opening to from one-half inch up to one and one-half inches for cylinders of the largest size, and, since the movement of the valve takes place chiefly when it is open and relieved of the pressure of the steam, the wear, and also the power required to operate the valves, is reduced to a very small amount, and lubrication is made easy.

The valve gear is simply an arrangement of links, rock shafts and slides for transmitting the motion of the eccentrics to the valves. Its construction throughout is unusual, as compared with valve gears containing dash pots or tripping devices, in that provisions are made for securing at all times smooth and quiet running. Every part subject to wear is made adjustable, and since the movement of the parts is small and the bearing surfaces are large, adjustment to insure quiet operation is necessary only at infrequent intervals. The rock shafts, pins and links are made of open-hearth steel. Connecting links are fitted with bronze heads having quick taper-key adjustment, and the rock-shaft bearings are babbitted and are easily adjusted. The valve gear is arranged so as to equalize the cut offs at both ends of the cylinder at all loads. The eccentric operating the cut-off valves is controlled by the governor. The main valves are driven by a fixed eccentric



A Solid Piston with Packing Rings.
Fig. 176.

controlling the admission of the steam and the opening and closing of the exhaust. One valuable feature of this arrangement is its perfect flexibility. Any one of the four operations of admission, cut off, release or compression, and for either end of the cylinder, can be varied independently of the others by adjustment of the gear. On multi-cylinder engines the governor usually controls the cut off on all the cylinders so that the work is divided equally among them and the drop in temperature of steam kept the same in each; hence the engine works as economically as possible under variable loads without the necessity of any hand adjustment.

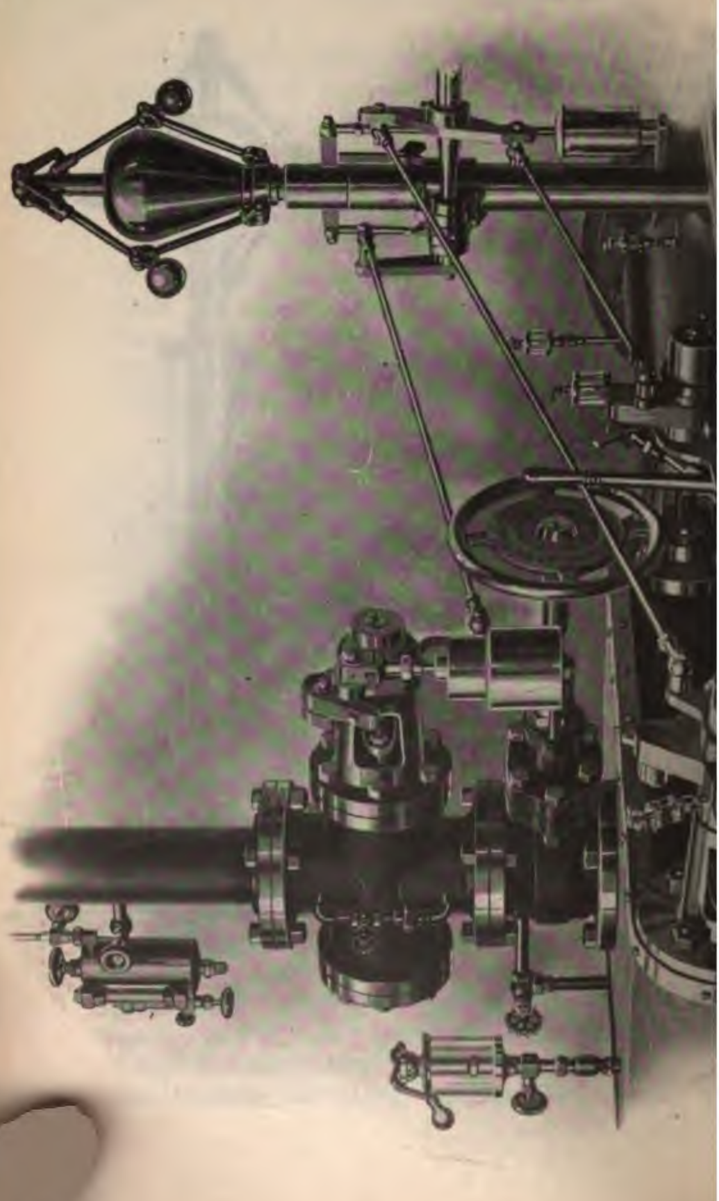
THE BUCKEYE ENGINE.

The distinguished features of this engine are the **Riding cut-off valve** and the **governor.**

A sectional view of this valve is shown in Fig. 185, which represents a section of a single engine cylinder and valves. Both the main and cut-off valves are cylindrical, the cut-off valve working within the main. Both valves are perfectly balanced and both have an absolutely uniform travel, which overcomes all tendency to uneven wearing of surfaces and as this travel extends beyond the seat surfaces there is no shouldering.

It contains the only perfectly balanced cylindrical valve in existence with which a riding cut-off valve can be used. All attempts to use unbalanced valves with riding cut-offs for automatic cut-off regulation have failed from the excessive friction and wear involved, for, as should be understood, the admission of the full boiler pressure to the valve constantly is one of the conditions necessary to perfect regulation of cut-off, and the realization of its benefits in the way of steam economy. In the common "throttling" engine, the valve is protected

Governor on Murray Corliss Engine.
Fig. 177.

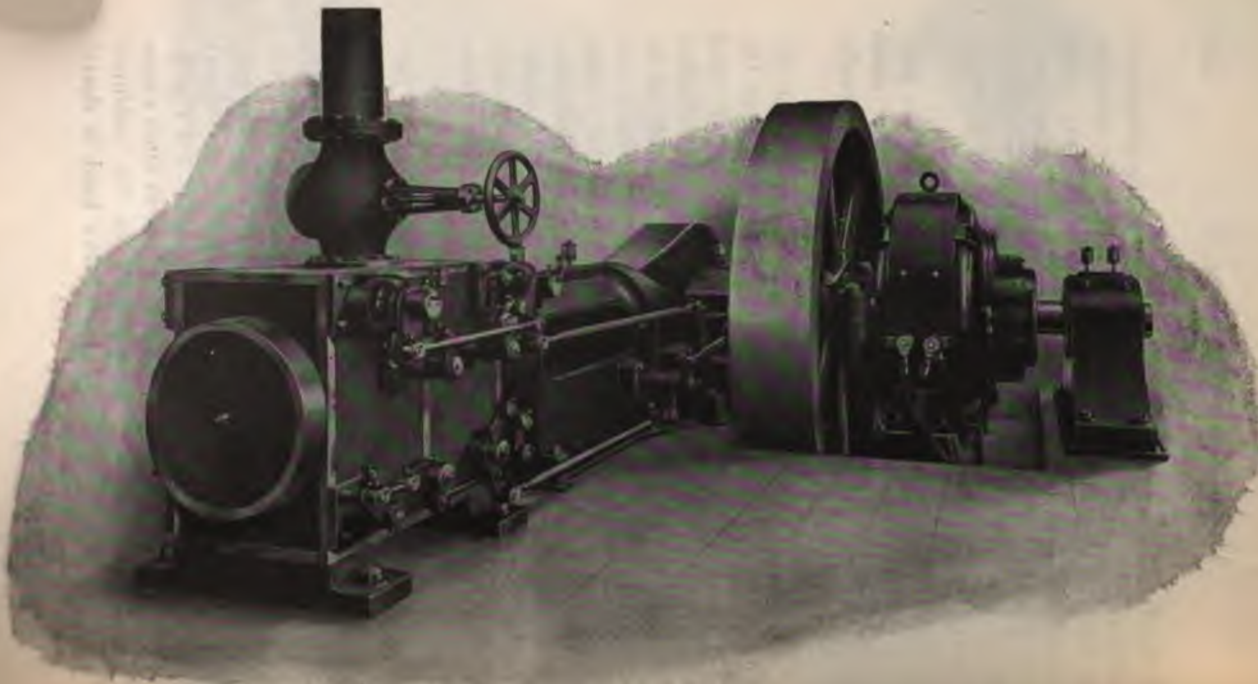


rom the full boiler pressure by the throttling process of regulation; hence, unbalanced valves can be used on them; but when the riding cut-off is the regulating agent, it enjoys no such protection, and if such a pressure is carried as good economy requires, and which may be easily sustained by other parts of the engine, its early destruction is inevitable.

Buckeye Governor.—In Fig. 186 is shown the governor used on this engine, which is the **pioneer shaft regulator,** from the fact that it was the first successful regulator of its type ever produced.

Safety.—The governor being secured directly on the engine shaft, and driving its valve as **positively** as the main valve, through an eccentric rod, rock shaft, and valve stem, the danger of the engine becoming detached from it and destroying itself and the lives of those in its vicinity, is entirely obviated. Such danger always impends when connecting mechanism between the engine and its regulator (particularly belting) is used. Instances of disaster to the engine and driven machinery, involving in many cases the loss of life, from the accidental detachment of the governor from the engine, are numerous.

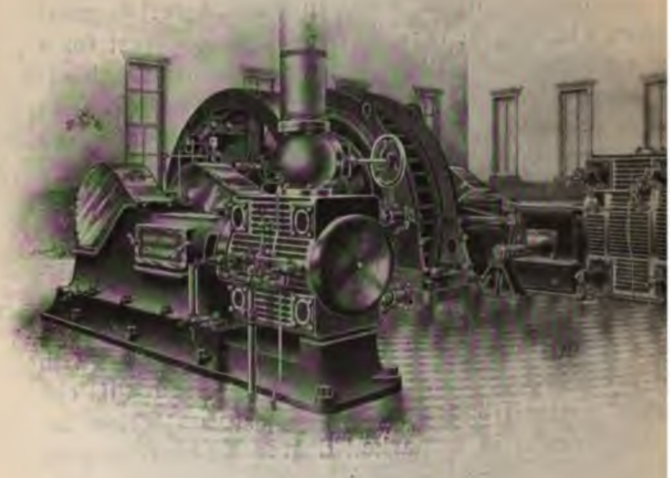
Regulation.—The construction of the governor permits such an adjustment of the centrifugal and centripetal forces to each other as will give in each case as close regulation as the nature of the conditions which affect the action of the governor will permit. If the machinery driven contains in itself considerable momentum to assist that of the fly wheel, and is not subject to sudden and extreme changes of resistance, the conditions are favorable to close regulation, and in such cases the variation of speed can, if desirable, be confined within 1 per cent, or less; but when the load is desti-



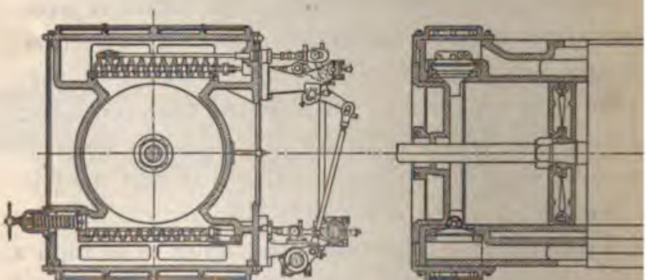
The Hamilton Corliss High Speed Engine.

momentum or **vis viva**, and is subject to great
dden changes, it may be necessary to adjust for a
r variation, according to the nature of the load;
any case much closer regulation can be had than
sible with the ordinary or pendulum governor, and
se as the conditions would permit with any system
ulation. The percentage of variation is adjustable
l, by varying the amount of initial tension given
governor springs—the more initial tension the
the regulation, within the limits beyond which the
sary stability of equilibrium would be lost.

t is admitted that this governor is "saddled with
ity of actuation as well as regulation," but this cir-
ance, so far from being injurious to its action, ac-
improves it in a **marked degree.** The resistance
d by the cut-off valve is intermittent, occurring
every revolution. While it lasts its tendency is to
the weights inward, and it undoubtedly does so,
gh the power of the governor is such that the dis-
nce is not perceptible. But slight as it is, it is
ient to keep the levers working slightly on their
ts, so that **all the friction about its joints is over-
e four times each revolution,** twice in each direction;
e if any new position of the levers is required, they
attain it at the first impulse in the required direc-
, without having to wait for a sufficient change of
ed to overcome the friction. Thus it is that the fric-
n of the cut-off valve neutralizes the effect of friction
the joints of the governor, **and the result is as high a
gree of sensitiveness to minute changes of load and
am pressure as if all parts were absolutely friction-
ss.**



The Harrisburg Four-Valve Engine.
Fig. 180.



Gridiron Valve and Valve Gear of the McIntosh-Seymour
Fig. 184.

SPECIFICATIONS FOR CORLISS ENGINE.

We propose to furnish you .... in accordance with the following specifications:

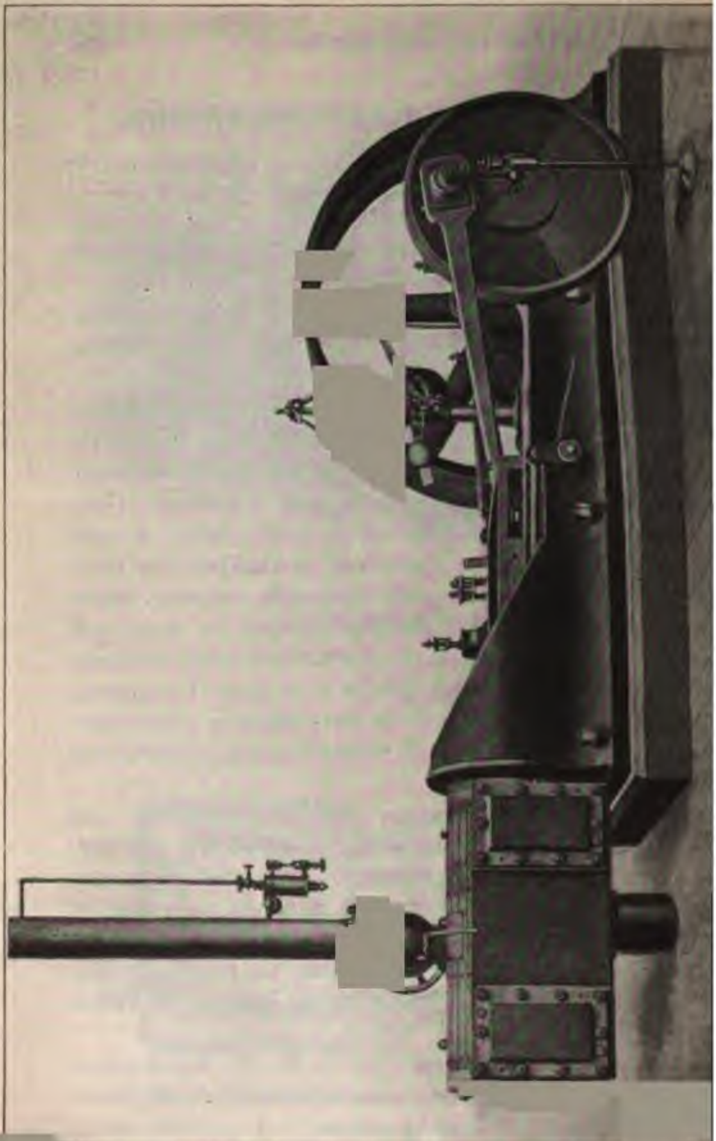
Type of Engine.—Engine to be of our .... type; and to run at ...... revolutions per minute with .... pounds steam pressure .... hand.

Cylinder Dimensions.—Diameter of H. P. cylinder .... inches. Diameter of L. P. cylinder ...... inches. Length of stroke ...... inches.

Material and Finish.—Shaft and connecting rods to be of best quality hammered wrought iron, free from flaws or other imperfections, and to be nicely finished. Pistons and eccentric rods, crank and crosshead pins, also wrists of valve gear to be of best quality forged steel. Great care will be exercised in making the castings of best quality as regards strength, wearing qualities and smoothness. All castings subject to wear will be poured from special heats of charcoal iron mixture. All parts will be made to gauge and interchangeable. Workmanship and finish will be first class in every particular. Engine to be primed, rubbed down, painted and varnished.

Guarantee.—We guarantee the workmanship and material in the engine to be first class, and we will furnish without charge a duplicate of any part that may prove defective in material or workmanship, provided an inspection proves the claim, within one year after engine is started. We guarantee the engine to run smoothly and in a proper manner, without undue heating or vibration.

Conditions of Operation (300 I. H. P. Noncondensing).—The engine is to run noncondensing at 100 lutions per minute. Steam pressure 125 pounds the atmosphere. Back pressure 15 pounds absolu



maximum load for which engine is intended equals 400 I. H. P. The engine is to operate at highest efficiency with load equal 300 I. H. P. The average load will equal 175-200 I. H. P.

Speed Regulations.—The speed regulation shall be within 1.5 per cent above or below normal.

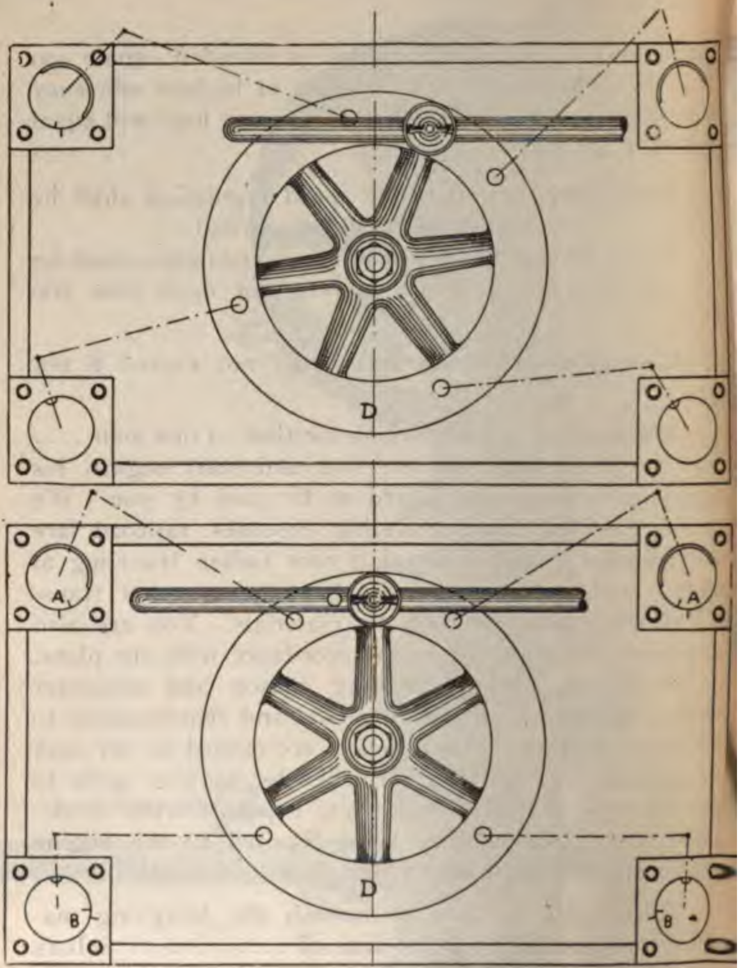
Piston Speed.—The piston speed regulation shall be not less than 560 feet per minute, nor more than 600 feet.

Clearance.—The clearance shall not exceed 8 per cent.

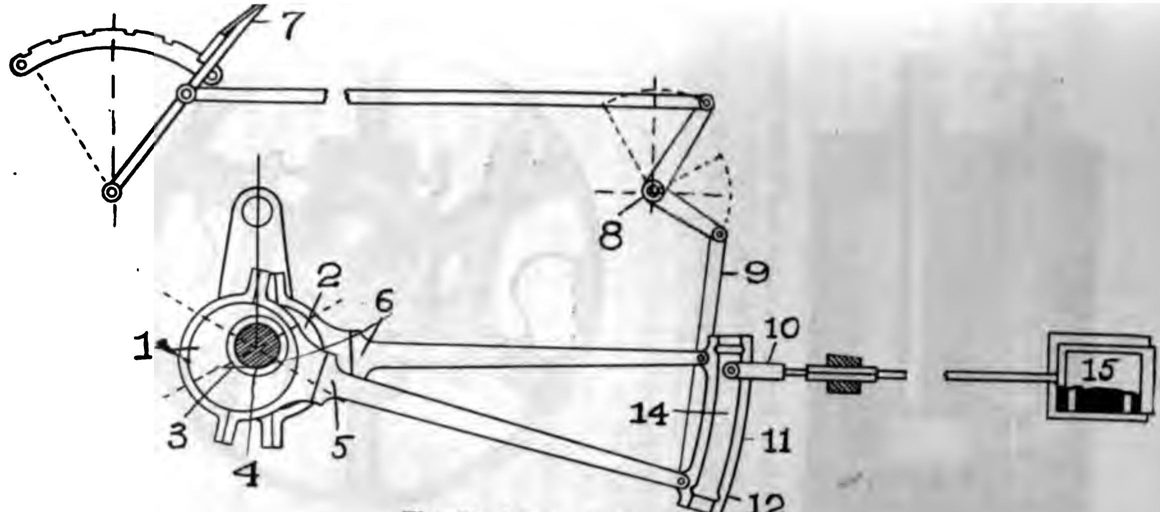
Erection.—We will furnish the time of one man .... days to superintend the erection and start engine, his traveling expense and board to be paid by you. We consider as legitimate traveling expenses, railroad fare and transfer charges, sleeping cars (when traveling at night), meals enroute, excess baggage or other transportation charges on tools or materials. You are also to prepare the foundations in accordance with our plans, do all piping, packing, belting, mason and carpenter work, and furnish all laboring help and requirements to facilitate erection. When delays are caused to our man by material or labor not furnished by us, you agree to pay his time at $5.00 per day and expenses while so delayed; our responsibility being limited to the engine proper and the accuracy of our plans.

Price.—Wé propose to furnish the foregoing machinery as specified for the sum of .... dollars ($........).

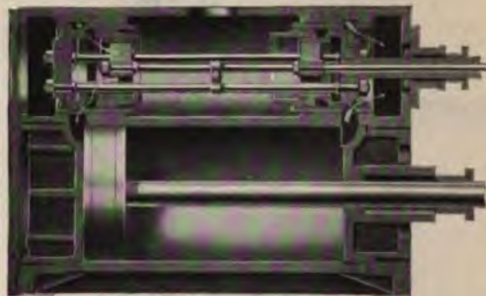
Terms of Payment.—Payment to be made as follows: .... when engine is ready for shipment; balance ...... days after shipment.



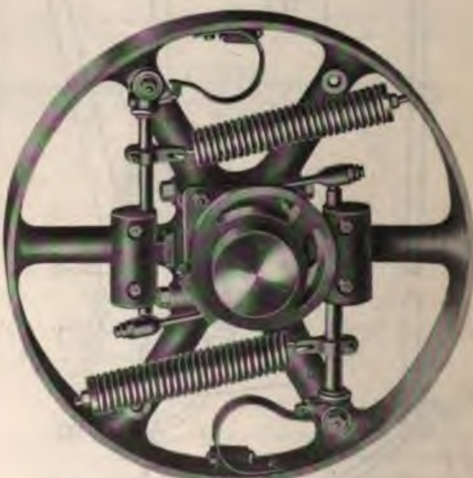
Adjustment of Corliss Valve Gear.
Fig. 182.



The Stephenson Link Motion.
Fig. 183.



Section of Buckeye Engine Cylinder and Valve, Showing Ri
Cut Off.
Fig. 185.



The Buckeye Engine Governor.
Fig. 186.

CHAPTER XVIII.

CONDENSERS.

eory of the Condenser.—When a vessel is filled eam at atmospheric pressure, and the steam is ed by bringing it in contact with cold water, the ·ill again appear in a liquid state, but will occupy 1669 part of its original volume. The heat of m passes into the cold water, raising its tem- · in proportion to the amount the temperature of m was lowered.

ve take a cylinder fitted with a piston, and con- closed end to a vessel filled with steam, upon ing the steam in the vessel, the atmospheric · on the piston will force it down, there being a pressure of about 15 pounds to the square inch, ; the pressure of the atmosphere on the one side iston; and there will be a partial vacuum on the de of the piston. This vacuum is created by ng the volume of the steam which formerly filled volume 1669 times as small.

: first steam engines constructed were conden- atmospheric engines, the steam being condensed :ylinder itself, and the weight of the atmosphere ng the power to force the cylinder down, the live ›eing used only to force it up against the weight atmosphere.

e waste of steam, and the other great disadvant- condensing the steam in the cylinder, are ob-

the year 1765 James Watt first condensed the in a separate chamber from the engine cylinder, of using a spray of water injected into the cylin- :lf after the piston had completed its stroke.

This was the **first step** in the direction of increasing the efficiency of the engines then in use, and from which beginning has been developed the multiple expansion condensing engines.

Jet Condensers.—Where a sufficient quantity of water is available suitable for **boiler feeding** purposes, the **jet condenser,** being the simplest and easiest method to operate, is preferable for condensing purposes.

In Fig. 187 is shown a complete installation of a jet condenser.

Directions for Installation of Jet Condenser.—The injection opening should not be more than 20 feet above the surface of water supply.

The injection or suction pipe must be full size of the opening given on the condenser. If this pipe is long, say over 80 feet, a larger pipe must be employed; for increased distances its diameter should be further increased. The condenser can be located on either side of the air pump, so that the injection pipe may lead to the condenser, in the most direct way, and with as few bends as possible.

Provide the injection pipe with a strainer to arrest foreign matter; also, provide it with an injection valve, placed within easy reach of the engineer to regulate the supply.

In all cases, where it is possible to do so, an exhaust relief valve should be placed in steam pipe from the engine to condenser so as to relieve to the atmosphere. Conditions may arise wherein the safety device provided with the condenser may be of no service, through no fault of the condensing apparatus, however; so that the installation of the relief valve is a wise precaution.

The plan of installation given is one that is the most practicable in the greatest number of cases, as it

admits of placing the condenser nearer the level of supply of injection water. Condenser can, however, be placed on the same floor with the engine, the injection water level and other local conditions permitting.

Ample and convenient hand-hole plates should be provided, so that the operator may inspect condenser, and remove all extraneous matter that may be lodged therein by the injection water.

It is absolutely necessary that the steam pipe, injection water pipe, all valves and auxiliary pipes should be **absolutely** tight, as the efficiency of the condenser depends on a high vacuum and in order to obtain this every joint must be tight.

Instructions to Engineer.—A good vacuum cannot be made unless you have all piping, valves, joints, etc., tight, or if your engine takes in air at the stuffing-box of valve stem or piston rod.

Never start your engine without running the air pump, unless you can exhaust direct to the atmosphere.

Before starting the air pump, drain its steam cylinder of condensation by means of its drain valves; open the exhaust relief valve.

Start the air pump and then open the valve on injection or suction pipe just enough to admit the required amount of water for condensing when engine is running under full load.

Start your engine and close the exhaust relief valve.

The slight pounding is a good indication; it means that your water piston is slightly ahead of the water as it should be. Run at a piston speed to just keep in advance.

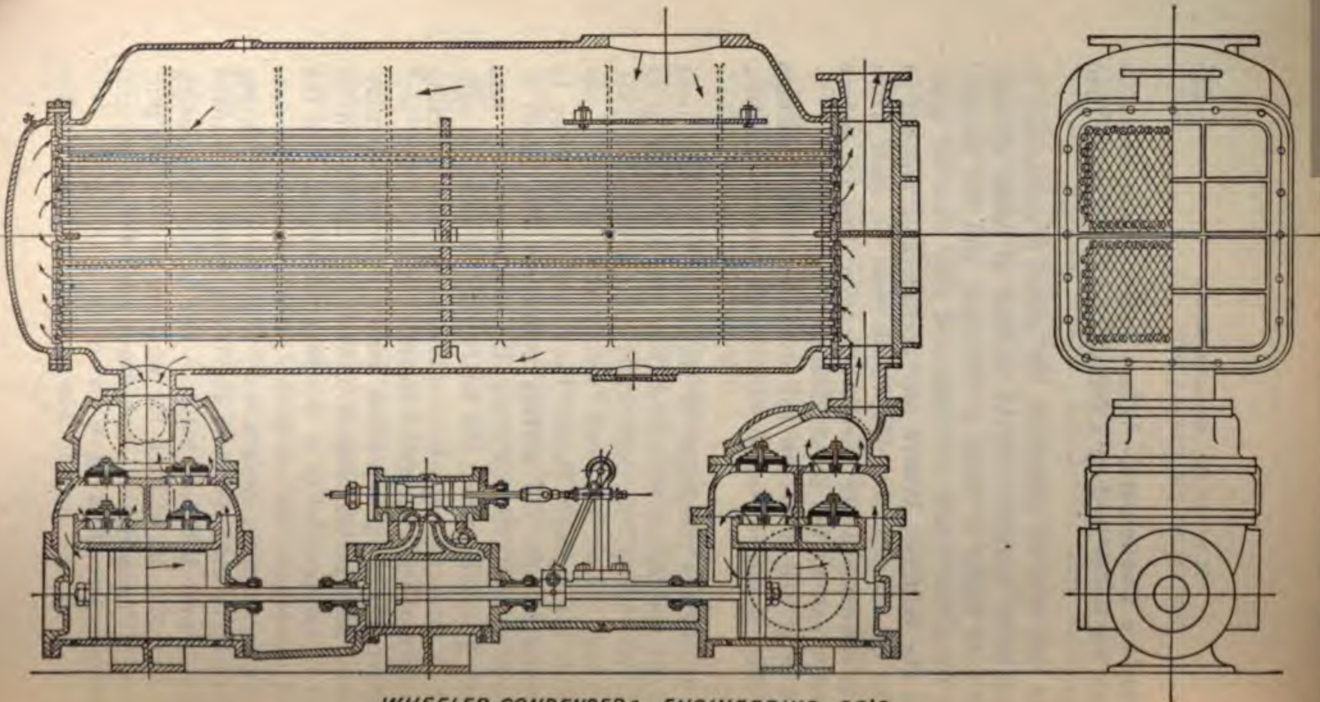
Be economical in the use of injection water; using but enough to keep the desired vacuum and maintain a temperature in your hot well of from 100 to 120 degrees.

Surface Condensers.—Where water is not available suitable for boiler feeding a surface condenser must then be used.

In this type of condenser the steam is condensed in a condensing chamber on the **surface of tubes** through which cold water is made to circulate, and the distilled water from the steam so condensed may then be again fed to the boilers. Where any considerable amount of cylinder oil is used, some provision must be made when surface condensers are used, to remove this oil **before** the water can be fed to the boilers.

In Fig. 188 is shown the usual form of a **surface** condenser mounted on combined air and circulating pumps.

The surface condenser is the modern development of the jet condenser, so called from the introduction of a "jet" or "spray" of cold water into a closed vessel, from which the air has been exhausted, in intimate contact with the exhaust steam, thus causing the same to be condensed. In the **surface condenser** the result is obtained without commingling the exhaust steam and circulating water, so that the latter may be alkaline, salt, muddy or impregnated with impurities, without affecting the quality of the condensed steam. Again, in the "jet" condenser, the air pump must handle both the circulating water and the condensate, introducing an element of danger in the possibility of flooding the engine. In the surface condenser, the air pump performs only its natural duties, namely, maintaining a vacuum and caring for the condensed steam, which, when suitably cleansed of oil, is a pure hot feed water. The heated circulating water may also be utilized for washing and dyeing purposes, as it has not been in contact with the steam and is, therefore, free from oil.



WHEELER CONDENSER & ENGINEERING CO'S

SURFACE CONDENSER MOUNTED ON COMBINED AIR & CIRCULATING PUMP

The Wheeler Condenser, as shown in Fig. 188, is made both cylindrical and rectangular in shape. The improved rectangular design is strongly recommended, owing to a special arrangement for reducing the velocity of the steam, together with a large storage capacity, an extremely desirable feature in connection with large units, such as are encountered in electric light and power stations, rolling mills, blast furnaces, dredges, etc., where sudden and variable loads are to be provided for.

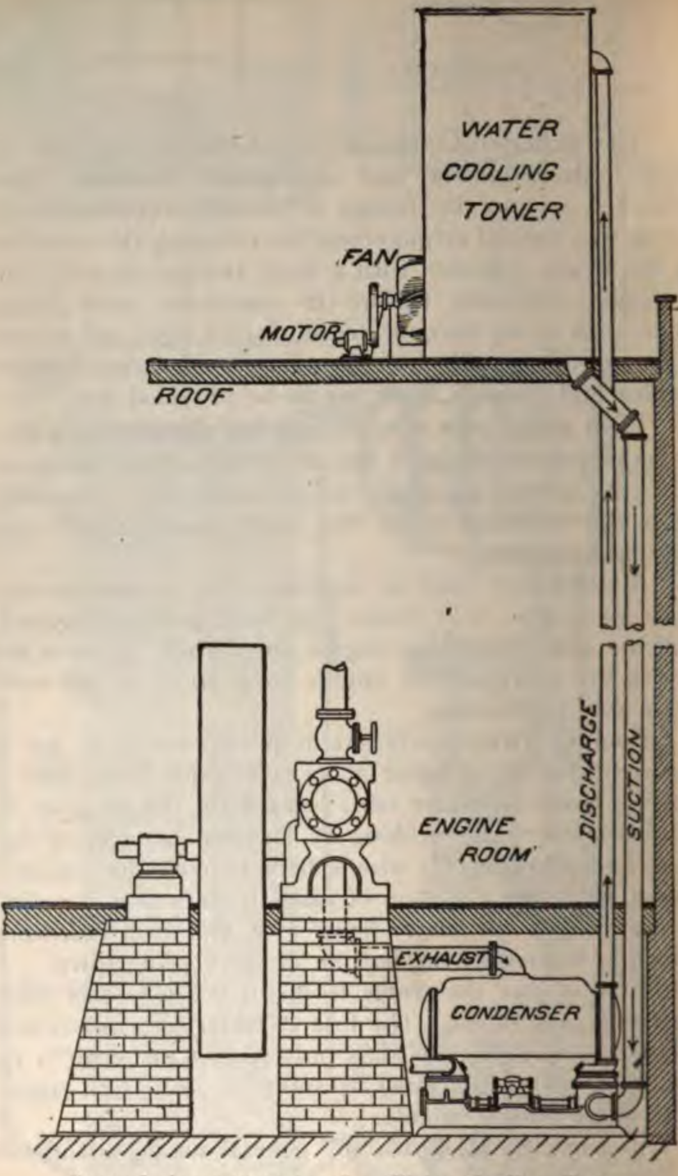
With **either** type of condenser the **quantity** of water to be circulated through the condenser should be from 20 to 40 times the steam to be condensed, depending upon the temperature of the water available for condensing purposes.

A condenser used to condense the exhaust steam from an engine, will reduce the back pressure against which a non-condensing engine must work, so as to **increase** the power of the engine from 20 to 30 per cent when run condensing.

Cooling Towers.—Where it is impossible to get a sufficient supply of water at an economical cost, then a cooling tower or water table is used for the purpose of condensation. This is done by locating same upon the roof, and allowing the atmosphere to cool the condensation, by using a system of mats or slats over the surface of which the water flows in a film to a reservoir which is located at the bottom of the cooling tower.

In this way the water from the condenser is used over and over again. The loss of water by evaporation when this method is used, is only from 5 per cent to 10 per cent, which loss must be supplied with fresh water from some outside source.

In Fig. 189 is shown the general arrangements of a Water Cooling Tower.



General Arrangements of a Water Cooling Tower.
Fig. 189.

In this arrangement the cooling tower is located on the roof of a building.

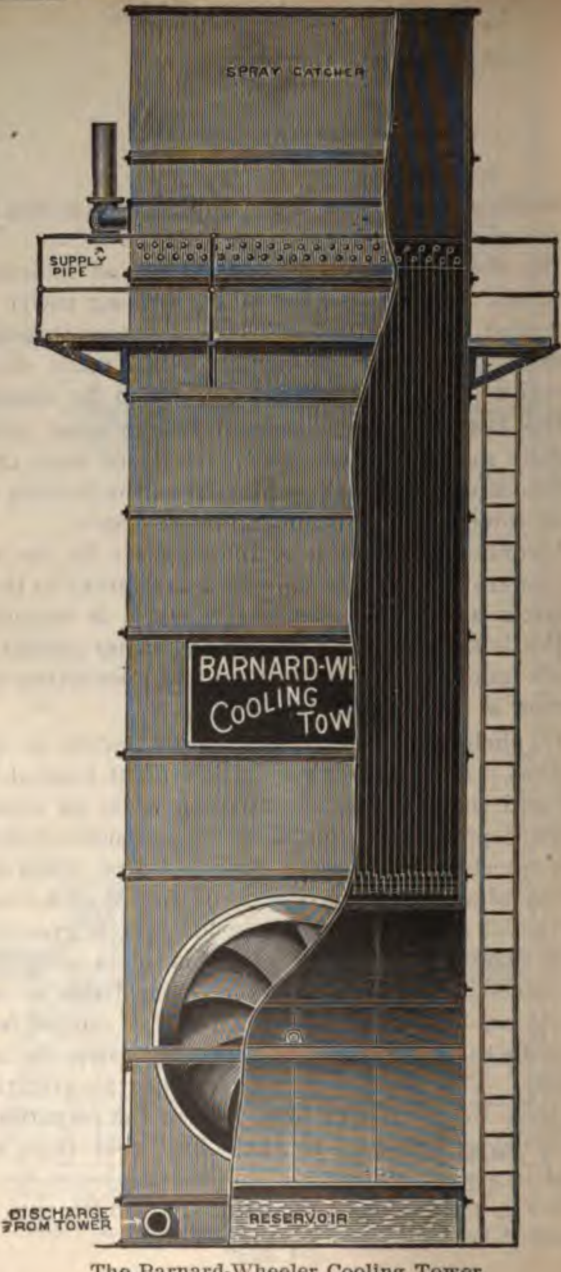
The discharge from the condenser, as indicated by the arrows, is led to the top of the cooling tower where it is cooled and returned to the condenser through the condenser pump, the connection being made direct to the suction pipe of the pump as shown in the diagram.

The hot condensation from the exhaust steam is cooled by making it flow over a series of mats or slats in a thin film to a reservoir located at the bottom of the cooling tower, as has been explained above.

A common reduction of temperature by the use of these towers has been from—say 130 degrees to between 85 degrees and 90 degrees, and when it is remembered that this is accomplished simply by taking advantage of nature's functions, the magnitude and importance of this invention is strongly accentuated.

The field into which this device enters is almost boundless. A mining or any steam plant located where water and coal are hauled or conveyed in an expensive manner is practically compelled to run non-condensing, unless resort is made to the cooling tower, when all the economy of a condensing system is gained at a comparatively small cost. Power house location is greatly simplified. Those which have been placed in remote positions, necessitating long lines of wiring, liable to serious leaks, to say nothing of additional cost of copper feeders, may, with the installation of a cooling tower be located centrally. The same argument applies to artificial ice factories. Brewers have long known the importance of such a device. Owing to their first cost their use is limited to a great extent.

In Fig. 190 is shown the general arrangements of the Barnard-Wheeler Water Cooling Tower.



The Barnard-Wheeler Cooling Tower.
Fig. 190.

Construction.—The tower casing is preferably constructed of steel plates. Within the tower are hung a number of mats of a special steel wire cloth, galvanized after weaving. The pump discharge is led to the top of the tower and distributed by a suitable system of piping to the upper edge of the mats, over the surface of which it spreads in a thin film, compelling a partial interruption of the flow, and continuously bringing new portions of the water to the surface, thereby exposing them to the evaporative and refrigerative effects of the air currents. The mats are practically a metallic sponge, capable of holding a large quantity of water in suspension, which accumulates and drips off into the supply tanks. To assist the cooling action, the air in immediate contact with the water is set in rapid circulation by means of the fan blower, which forces air into the lower part of the tower and upwards between the mats. This may be driven by any convenient source of power, such as an electric motor, or from a line shaft, or by an independent steam engine.

With the Barnard-Wheeler system of cooling towers and condensers there is no difficulty in reducing the temperature of the condensing water from 40 to 50 degrees, or sufficient to maintain a vacuum of 23 to 25 inches, thus insuring fuel saving and greater efficiency of the plant.

As there is but a small loss due to evaporation—say, not exceeding 3 per cent of the water passing through the tower—steam plants are enabled to operate condensing, independent of a natural water supply.

The operating power requirements of this condensing installation is but 2½ to 4 per cent of the total I. H. P. output of the main engines, according to their size. With fanless tower this ratio is considerably reduced.

Owing to the light weight per square foot of foundation area, this cooling tower is admirably adapted to roof installations, which is an important feature where ground space is not available.

Causes of Imperfect Vacuum.—One of the most serious objections to the use of condensers is the difficulty in maintaining a sufficiently low vacuum.

An imperfect vacuum, that is, a low vacuum, is usually due to one of three causes, being namely: 1, the amount of condensing water may be insufficient; 2, the air pump, which is used to remove the air which enters with the steam, may be **out of order**; 3, there may be **air leaks** in the chamber itself permitting the entrance of air from the outside.

CHAPTER XIX.

COMPOUND ENGINES.

Advantages of Compounding.—A compound engine has two cylinders of different size. Steam is admitted first into the smaller one, called the **high pressure cylinder**, and, after a certain amount of expansion has taken place is exhausted into the larger or **low pressure cylinder**, where it is further expanded before being finally exhausted into the atmosphere or condenser.

The object of compounding engines, is to obtain economy in the use of steam by reducing the **cylinder condensation.**

In the single engine, a great portion of the heat of the entering steam is given up in heating the wall of the cylinder. This loss of heat greatly lowers the economy of the engine, and it is to avoid this as much as possible that engines are compounded. The condensation of the steam by the much cooler walls of the cylinder is called cylinder condensation, and it is to lessen this as much as possible, that the many different types of engines have been designed.

In the single engine, a large part of the heat which has been given up to heat the cylinder, is again taken up by the condensed steam during expansion and the exhaust stroke, but finally is wasted through the exhaust pipe. In the **compound** engine, all the heat which is lost during admission, and which is again taken up by the steam during expansion and exhaust, is not lost by being discharged into the atmosphere or the condenser, but is discharged into the **low pressure cylinder** where it is used again in heating that cylinder, and

therefore decreases the amount of the entering stea that is so wasted.

In compound engines, the only loss from cylinde condensation is therefore that which takes place in th **low pressure cylinder**, as the steam is discharged from the high pressure cylinder before its temperature is much reduced. We therefore see from the foregoing explanation, that the cylinder condensation in the compound engine will be considerably less than one-half of that in the single engine.

There is also a **mechanical advantage** in compounding the engine, as two cranks may be used, set at right angles to each other, so that when one is on a dead center, the other is at a position of nearly its greatest effort. This makes a dead center impossible, an thereby enables the engine to run more uniform.

By thus compounding an engine at least **20 per cen** can be saved, that is, the compound engine is 20 pe cent more economical than the single engine.

Construction.—The low pressure cylinder must b made **larger** than the high pressure cylinder, on accoun of the pressure of the steam being less when it reache this cylinder than when it entered the first cylinde This cylinder must therefore contain a greater volum of steam, and must have a greater piston area agains which the steam can act.

Systems.—There are several different systems o compounding an engine, being namely, 1, the **tande compound,** in which both cylinders are in line and bot pistons arranged upon the same rod; 2, **a cross com pound,** which consists of practically **two** engines, sid by side and connected to the same shaft. In this for of compounding, both cylinders operate **separate** crank which may be set at right angles to avoid dead cente

and to distribute the load more evenly about the crank shaft, or, as is rarely done, the cranks may be set opposite each other.

In Fig. 191 is shown a sectional view of a tandem compound and a cross compound engine with proper crank connections.

The Receiver.—This consists of an enclosed vessel of at least the same capacity as the high pressure cylinder, and into which the **high pressure** cylinder exhausts. The steam passes from the receiver into the low pressure cylinder.

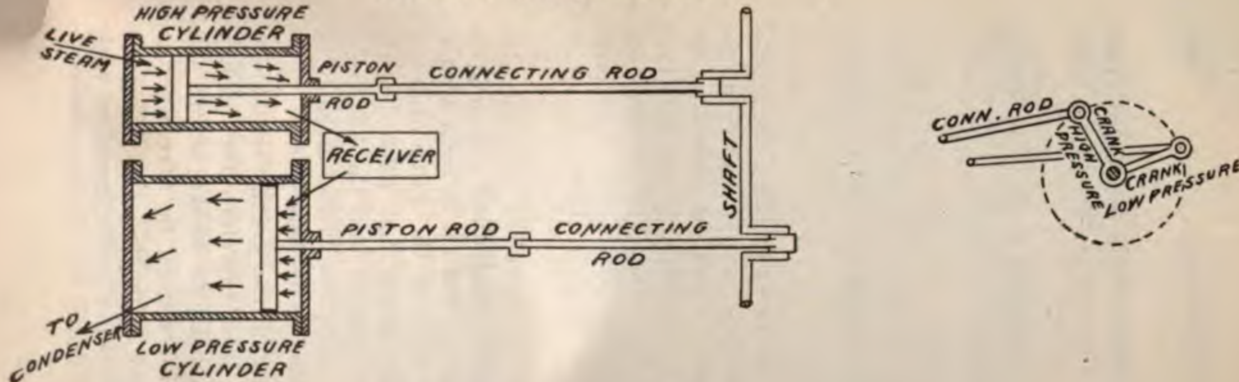
A receiver is necessary for those engines, the cranks of which are set at right angles. For instance, in the two cylinder engine the cranks would be placed 90 degrees apart, and therefore one cylinder could not take steam during the time that the other cylinder was exhausting. Therefore, an enclosed chamber, or **receiver** as it is called, is necessary in which to store the steam until it is wanted.

Most compound engines are therefore supplied with a receiver, though in a **tandem compound** engine it is not a necessity, as the cranks are not set at right angles, and therefore **both** pistons start at the same time on their stroke, and hence the steam can pass directly over from the high pressure cylinder into the low pressure cylinder. If a tandem compound cuts off early in the stroke, a receiver will then be necessary.

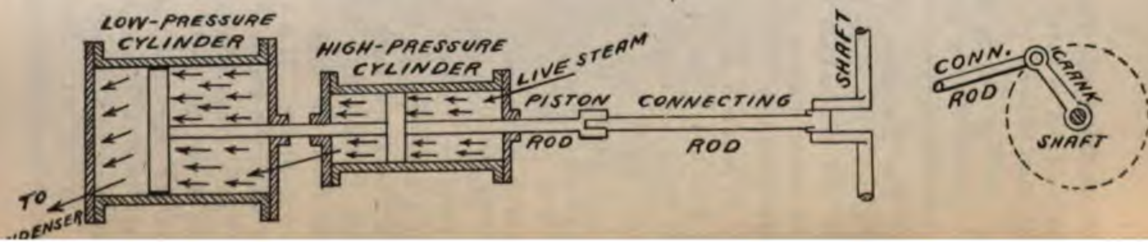
In a **cross compound** engine the cranks are almost always set at right angles, and therefore the leading cylinder has completed one-half its stroke before the other begins, consequently there must be a receiver to take care of the high pressure exhaust.

In Fig. 191, a receiver is shown in connection with a cross compound engine.

CROSS COMPOUND



TANDEM COMPOUND



The Reheater.—This is a modification of a receiver, containing coils, or nests, of small pipes through which the high pressure steam circulates and becomes **reheated** before being again used in the low pressure cylinder.

Construction.—The exhaust from the high pressure cylinder enters at one end of the heater, and is compelled by baffle plates to flow over and around these tubes, finally passing out at the other end of the chamber into the low pressure steam chest. Live steam at boiler pressure is made to pass **through** the tubes around which the exhaust steam circulates, and in this way the exhaust from the high pressure cylinder can be reheated before it enters the low pressure cylinder. The usual form of a reheater consists of a cast iron or wrought iron shell, having at one end a tube plate secured between the shell and cover. A large number of wrought iron boiler tubes are expanded into this tube plate, and these boiler tubes are expanded at the other end also into a tube plate which is bolted to the head. One end of the reheater is closd by a cover through which a steam pipe and an air drain pipe pass. A drain pipe is inserted through the lower head and connected to a trap. The drain from the shell is also led to a trap.

Economy.—It is not **always** economy to use a reheater, as the amount of **live steam** used, may cause a loss instead of a gain.

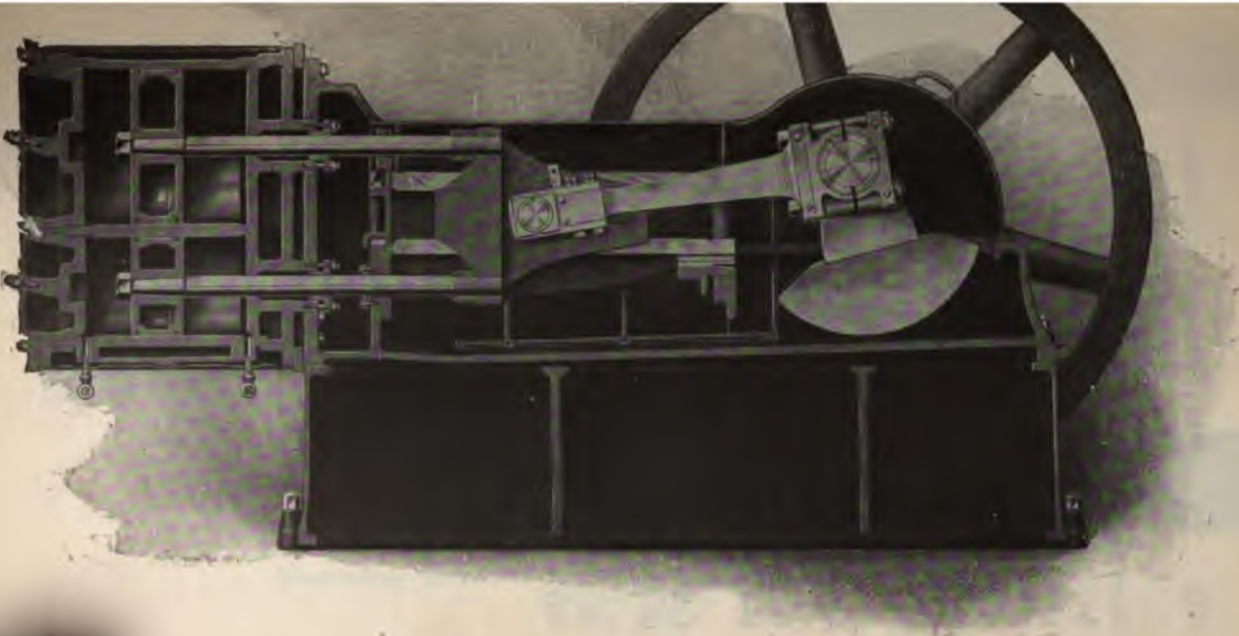
Test.—In order to determine if there is any economy in its use, place a thermometer in the low pressure exhaust. Should the temperature of the exhaust steam be **higher** than that corresponding to its pressure, the reheater is wasting steam, and should be abandoned.

THE AMERICAN DUPLEX COMPOUND ENGINE.

The most conspicuous features of this engine, as seen from Fig. 192, are its **compactness** and **simplicity**. It will be seen from this cut that it requires no more floor space than the simple engine, and the valve gear, consisting of a **single** valve rod and valve, has exactly the same number of parts as the valve gear of a simple engine.

Progress in engineering is generally either in the direction of a better result, or a simpler or more compact machine, and generally a gain in one of these directions is accompanied with a loss in the other, so that the two must be balanced against each other in determining the real advantage. This **Duplex Compound Engine** is one of those happy combinations in which a great gain in simplicity and compactness is also attended with an appreciable gain in efficiency.

The Valve.—The valve used in this engine is an improved form of **piston valve,** which provides a very practical means of adjustment for wear. It is well understood that the wear of a piston valve in a horizontal engine occurs on the lower half, and is caused by the friction due to the weight of the valve. Part of the wear is on the valve and part in the bore of the valve chest, and the leakage is over the upper half of the valve through a crescent shaped opening. The lower half of the valve which has been worn by contact with the bore of the valve chest, still fits the bore and is practically steam tight, and the upper half of this valve would fit the upper half of the bore perfectly if it could be brought into contact with it. This is just what is provided for in the construction of this valve, by splitting the valve horizontally, so that the upper half may be separated



The American Duplex Compound Engine.
Fig. 192.

from the lower and brought into contact with the upper half of the bore. This makes an **oval,** not a cylindrical valve, but a cylindrical valve would no longer fit the bore, which has been worn into an oval. To provide for the adjustment of this valve, thin sheets of rolled copper are placed between the halves.

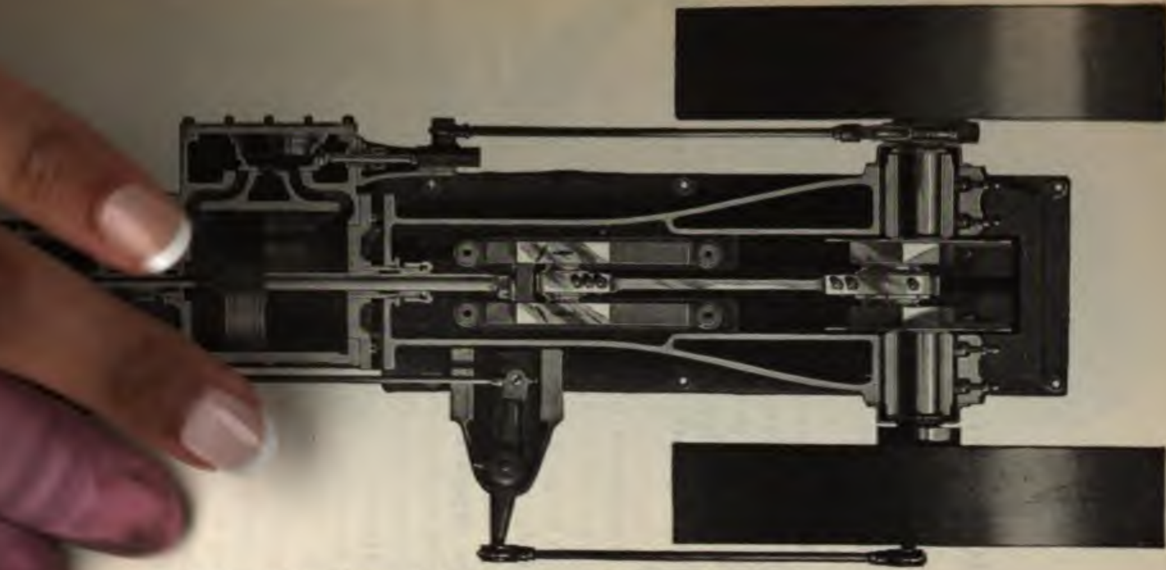
In Fig. 193 is shown a longitudinal section of the Skinner Tandem Compound Corliss Engine.

In Fig. 194 is shown the Fulton Cross-Compound Corliss Engine.

In Fig. 195 is shown the St. Louis Cross-Compound Belted Engine, the tandem type of which engine has been described.

In Fig. 196 is shown the McIntosh-Seymour Cross-Compound Vertical Engine. The general construction of this engine has also been described.

In Fig. 197 is shown a sectional view of the **valves** of a Compound Ideal Engine, the valve on this engine having been heretofore described.



Longitudinal Section of the Skinner Tandem Compound Engine,
Showing Valves.
Fig. 193.

CHAPTER XX.

QUESTIONS AND ANSWERS ON PRECEDING CHAPTERS.

Q. What is a steam engine?

A. It is an apparatus for converting heat into mechanical power.

Q. Who constructed the first practical engine?

A. Thomas Savery in the year 1693.

Q. For what purpose was it used?

A. For pumping water out of a mine.

Q. Who greatly improved upon this engine, when and how?

A. Newcomen in the year 1705 by using a piston which worked in a cylinder.

Q. Who greatly improved upon the Newcomen engine, introducing the first type of the modern engine?

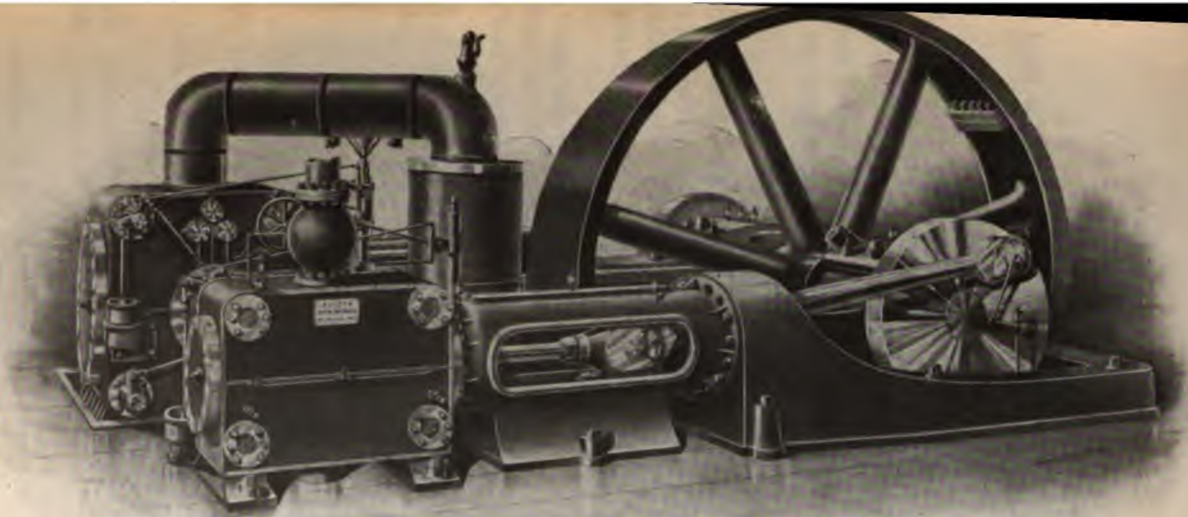
A. James Watt in 1764. He first introduced the use of the **separate** condenser and a **closed** cylinder, together with a great many changes which have been but little improved upon even to the present day.

Q. How are engines classified?

A. According to the work for which they are built, being viz.: (1) stationary, portable, etc.; (2) from the arrangement of the cylinders, as, simple, compound, triple expansion, etc.; (3) according to the character of the valves to control the distribution of the steam, as plain slide valve, automatic cut off, Corliss, etc.; (4) according to the motion of the piston, as reciprocating and rotary.

Q. How are these divisions subdivided?

A. Into (1) condensing engines, (2) non-condensing engines, (3) single acting engines; (4) double acting engines.



The Fulton Cross-Compound Corliss Engine.
Fig. 194.

Q. What is a simple engine?

A. It is an engine in which the steam is use pansively in only **one** cylinder.

Q. What is a compound engine?

A. It is an engine which has **two** cylinder steam being expanded **twice** before its final discha

Q. What is a non-condensing engine?

A. It is an engine in which the steam after h been expanded in the cylinder is discharged into t mosphere, or into a heating system.

Q. What is a condensing engine?

A. It is an engine in which the steam after h been expanded in the cylinder is discharged into a denser where it is brought in contact with some cc substance, by which it is **condensed** and a partial va produced behind the piston.

Q. What is the object of so condensing the st

A. It is to remove as much as possible the **pressure** on the piston, and to thus increase the effective pressure on it throughout its stroke.

Q. What are the reciprocating parts of an en

A. They are all the parts which move **bacl forth** either in a horizontal or vertical direction, viz.: (1) the piston, (2) the piston rod, (3) the head, (4) the connecting rod.

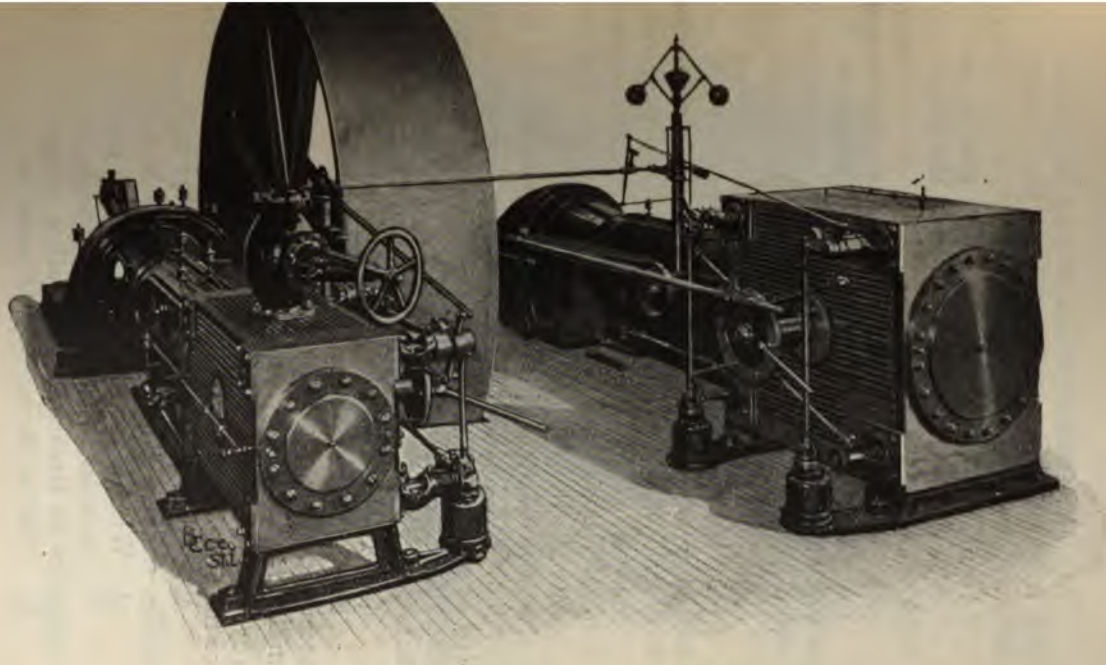
Q. What is the **cylinder** of an engine?

A. It is that part of the engine in which the p moves.,

Q. What is meant by the term head-end and c end of the cylinder?

A. The head-end is the end farthest away fro crank shaft, while the crank-end is the end neares crank shaft.

Q. What is meant by the **stroke** of an engin



The St. Louis Cross-Compound, Belted Engine.
Fig. 195.

A. The distance passed over by the piston in moving from one extreme position in the cylinder to the other.

Q. What is meant by the **valve gear** of an engine?

A. The mechanism by which the steam is distributed.

Q. What composes the valve gear of an engine?

A. The distributing valves, the eccentric, the eccentric strap, the eccentric rod, the rocker, and the valve stem.

Q. What is the eccentric, and what is its purpose?

A. It is a disc or crank keyed to the shaft so that its center and the center of the shaft do not coincide. It is used to operate the distributing valve or valves.

Q. What is a single valve engine, and what is a four-valve engine?

A. A single valve engine is one in which a single valve controls the admission and distribution of steam for both ends of the cylinder, while a four-valve engine is one which has separate valves for the admission of the steam to the cylinder, and for its discharge or exhaust.

Q. What is meant by the **cut-off** of the valve?

A. It is the point of a piston's travel at which the steam admission port **closes,** no further steam being admitted to the cylinder during the remainder of the stroke.

Q. What is the object of cutting off the admission of the steam?

A. So as to allow for expansion of the steam, thus saving steam which means the saving of **fuel.**

Q. What is the purpose of **outside lap** on a valve?

A. In order to cut off the steam before the piston completes its stroke, and thus allow expansion.

Q. What is the purpose of **inside lap** on a valve?

The McIntosh-Seymour Cross Compound Vertical Engine.

Fig 196.

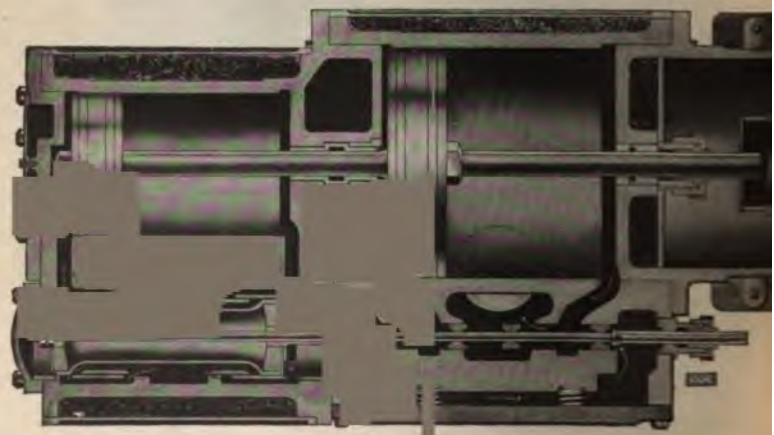
A. It is to close the exhaust port before the piston reaches the end of the return stroke, thus increasing the compression and forming a cushion of steam against which the piston strikes.

Q. What is meant by **lead?**

A. It is the amount that the valve leads the crank, for it is the space the steam port is open when the engine is on the center.

Q. How is the size of an engine indicated?

A. By the length of the **stroke** and the **diameter** of the cylinder.



Sectional View of Valve of Compound Ideal Engine.
Fig 197.

PUMPS.

Use.—Pumps vary greatly in design, depending on the character of work for which they are constructed.

They are now made to handle water, beer, molasses, acids, oils, melted lead, and such gases as air, ammonia and oxygen.

The different types used to cover this large field of work are defined as chain, diaphragm, jet, centrifugal, rotary and cylinder pumps.

It is only the last three types, viz.: rotary, centrifugal and cylinder pumps that are generally used in the field covered by this work.

Steam Pumps.—By steam pumps we mean those in which the propelling force is steam, and which is applied to the movement of the water, or other liquid, without the intervention of belting or gear wheels. Steam pumps are divided into two general classes, viz.: 1, direct acting pumps; 2, fly wheel pumps.

Direct Acting Pumps.—By this is meant a steam driven pump in which there are no revolving parts, such as shafts, cranks and fly wheels, the pressure of the steam being transferred to the piston or plunger through the use of a continuous rod or connection.

The direct acting steam pump was invented and developed by Henry R. Worthington in the year 1840.

The chief objection to the direct acting pump arises from the action of the piston or plunger being intermittent; that is, the column of water is started into motion at the beginning of each stroke, and comes to a standstill at the end of each stroke, thus not only making the flow of the water irregular, but subjecting the pump and the connecting pipe to serious strains.

Duplex Pumps.—In order to overcome the intermittent action of the single direct acting pump, about the year 1845 Mr. Worthington brought out what is known as the **duplex pump.** This is also a **direct acting** pump, the construction of the steam and water ends differing but slightly from that of the single direct acting pump, but the **mechanism** that operates the steam valve is entirely different, and the result produced upon the movement of the water or liquid also differs, as with this pump a **continuous discharge** is secured.

A duplex pump is nothing more than a **combination** of two single direct acting steam pumps coupled together, the steam valve of one being operated by the piston of the other pump.

The effect of this arrangement is to produce a **steady** flow of the water, or liquid, without the usual strains produced when the flow of the same is suddenly arrested and then started again, as is the case in single direct acting pumps.

In duplex pumps the two pistons move in **opposite** directions, making the action of the pump **continuous.** The valve has neither outside or inside lap, as there would be danger of the pump sticking on centers, and hence the steam cannot be used expansively. The steam valve is carried along by coming in contact with check or lock nuts placed on the valve stem.

Lost Motion.—In order to arrest the steam piston when it completes its stroke, and allow the other pump time to pick up the motion, thereby preventing the pump stopping altogether, a certain amount of **lost motion** between these check or lock nuts must be allowed. Should there not be **sufficient** lost motion, the pump will **short stroke,** if **too much** lost motion, the piston will knock out the opposite cylinder head, or will stop on

center. The lost motion allowed together with the auxiliary valve, simply take the place of a **fly wheel** to carry the pump over its centers.

Rule.—The rule is to allow as much as one-half of the width of the steam ports on each side of the lock nut, for lost motion.

Fly Wheel Pumps.—Are those pumps which rely upon a fly wheel to carry them over their centers. Owing to their many disadvantages they are not in general use.

Classification.—Pumps are divided into two general classes, viz.: (1) those having their valve gear outside, and (2) those having the valve gear on the inside, and hence having no moving parts visible except the piston rod.

Pumps are further divided into **single acting** pumps, which do their work through only one end of the cylinder; and **double acting** pumps, which is simply an engine and pump combined. In this latter class of pumps, the motion of the piston in one direction causes an **inflow** of water and a discharge at the **same** time at the other end, and on the return stroke the action is reversed, as the discharge end becomes the **suction** end. The pump is therefore double acting. The single acting pump is not in general use.

Ends.—The two ends of a steam pump are designated as the **steam end,** which is a complete steam engine, and the **water end** into which the water is drawn, and from which it is discharged by the piston or plunger.

To Adjust the Valves of a Duplex Steam Pump.—The steam chest cover must first be removed, and the glands in the stuffing boxes of the piston and valve rods be slackened so as to permit the rods to be moved freely through the packing. Bring the rocker arms into

a **vertical** position, as shown in Fig. 207. While this can be done **without** the use of a plumbline, for accurate work it should be used. When the levers are plumb, they occupy the position known as **mid-stroke**, and, were it not for the play necessary between the valves and the lock nuts on the valve stem, the valves would occupy the corresponding position known as **mid-travel**. As pump valves have no lap, when they are placed at mid-travel the ends of the valves should just cover the steam ports, the edges of the valves and the outer edges of the steam ports being then in line.

After placing the rocker arms plumb, measure the **width** of the steam port, and then set the valve squarely over the port, so that both steam ports on both sides of the pump will be entirely closed.

The space between the nuts and the lugs on the back of the valve should be equal to one half the width of the steam port, that is, if the valves are now to be moved in either direction, the steam ports would be **one-half open.**

As the valves will now be in a position to entirely prevent the admission of steam into the cylinder, it will be necessary to move at least one of the valves so as to open one of the steam ports.

The chest cover may now be put on, and the stuffing box glands tightened sufficiently to prevent leaking.

As the piston is in the exact center of its travel when the rocker arm is vertical and the valve covers both ports equally, the valves can therefore be adjusted by placing the **piston** in the middle of its travel. To do this, move the steam piston towards one of the cylinder heads until it comes in contact with it, and make a mark on the piston rod at the face of the stuffing box. Then move the piston to the opposite end of the cylinder and

make another mark on the piston rod. Then half the distance between these two marks is the middle of the travel of the piston, and it is only necessary to move the piston back until the middle mark is at the face of the stuffing box to center the piston.

In Fig. 208 is shown the proper position of the valve at the commencement of the stroke. As the valve has neither lap nor lead, the steam port is wide open, and at the opposite end the exhaust port is wide open.

Cushion.—In Fig. 209 is shown a method of cushioning the steam piston of a pump by the use of two ports at each end of the cylinder, instead of only one port as customary with slide valve engines. It will be seen that the exhaust is closed by the valve passing over first one port and then the other; in this way the compression of the steam is made gradual by the forming of a steam cushion between the piston and the cylinder head, thus arresting the motion of the piston gradually, and without shock or jar. A dash relief valve, not shown in the cut, is placed between these two ports at each end of the cylinder, which valve is regulated from the outside

Construction of the Water End of a Steam Pump.—The construction of the water ends of a single cylinder and a duplex pump is practically the same. As shown in Fig. 210, the water valves are carried by two plates or decks, the suction valves being attached to the lower plate or deck, and the delivery valves to the upper one.

The upper deck, and sometimes both decks, are removable. The valves are secured to the decks by means of bolts or long machine screws, which are screwed into the bridge across the port in the plate.

The valve works up and down on this bolt, it serving as a guide for the valve. A conical spring is employed

to hold the valve firmly to its seat, the spring being held in position by the head of the bolt, as can be seen from Fig. 210.

Water Valves.—These valves are of the flat disc type, with a hole in the center to enable the valve to raise easily on the bolt, which serves a double purpose of acting as a guide to the valve, and also to limit the travel, or lift, of the valve.

Lift.—In Fig. 210 is shown the lift of the valves, by which is meant the height that they are raised from their seats by the force of the incoming water. The lift of the valve is proportionate to the piston speed at which the pump is run, and it should be as **small** as possible, without causing too much frictional resistance to the water.

Slippage.—Pump slippage is a term used to denote the difference between the **estimated** and the **actual** discharge of the pump, and is generally expressed as a percentage of the calculated discharge. Thus when the slippage is given as 20 per cent, it indicates that the loss due to the slippage amounts to 20 per cent of the **calculated** discharge.

Slippage is mainly due to the time required for the suction and the discharge valves to close, and also to **excessive** speed. When the piston speed is too high, the water cannot enter the pump fast enough to **completely** fill the cylinder, and in consequence only a **partial** filled cylinder of water is delivered at each stroke.

This slippage, which is also due to the improper seating of the valve, affects considerably the **efficiency** of all pumps.

Air Chambers.—In order to steady the discharge of the water, air chambers are used on almost all pumps. The air which is contained in the water, being lighter than the water rises and fills this air chamber which is

usually placed at the highest point on the discharge chamber, and in this way forms a **cushion** to steady the flow of the water passing through the pump.

Operation.—The operation of the water end of a pump may be readily understood by referring to Fig. 210, which shows the **movement** of the water valves. The suction valves prevent the **return** of the water after it has entered the cylinder, and the discharge valve permits the **outward** passage of the water, but does not permit its return.

The water is not actually raised by suction, but by the **pressure** of air on the water outside the pump. The piston, or plunger, of the pump **exhausts** the air from the cylinder, thus forming a vacuum, and the **unbalanced** weight of the water causes it to rise within the pump, or pipe supplying the pump, filling the **vacuum** so formed. The limit of this lift for water is about 33 feet, because water of 1 inch area at this height has about the weight of the atmosphere, viz.: 14.7 pounds. Pumps rarely are in such perfect condition to lift water this height, as to do so all pipes and valves would have to be perfectly **air tight.** Ordinarily, pumps will not lift water more than from 22 to 25 feet.

As a vacuum is necessary for the operation of a pump where water or a liquid must be **lifted,** it is impossible for a pump to lift **hot water,** as the **vapor** therefrom fills the vacuum as fast as it is formed by the piston. Therefore, where a pump is required to handle very hot water, it must be placed **below** the water supply, so that the water will flow into the pump. Under such conditions, a pump can handle water whose temperature is 212 degrees, or above, without any special difficulty. The most **necessary** condition for the satisfactory operation of a pump, is a **full and steady supply of water.**

Pipe Connections.—The pipe connections of a pump should in no case be **smaller** than the openings in the pump, and both the delivery and the suction pipes should be as **straight** as possible. The flow of water in the suction pipes should not exceed 200 feet per minute, and not more than 500 feet in the delivery pipe for a duplex double acting pump.

Boiler Feed Pumps. Such pumps as are used for supplying steam boilers with their necessary water supply, are designated as **boiler feed** pumps. For ordinary pressures, they are usually made of the piston pattern.

The cylinders are generally brass lined. The valves are brass or of hard composition, with composition springs, as the pump must be suitable for handling hot water. Both single cylinder and duplex pumps are used for boiler feeding, but the duplex pump is more generally used, as it gives a most continuous action under all circumstances.

Selection of Pump.—As the **service** to which a pump is to be applied determines its type and general construction, when ordering or making inquiries as to the pump for any particular work, full information should be given in answer to the following questions, viz.:

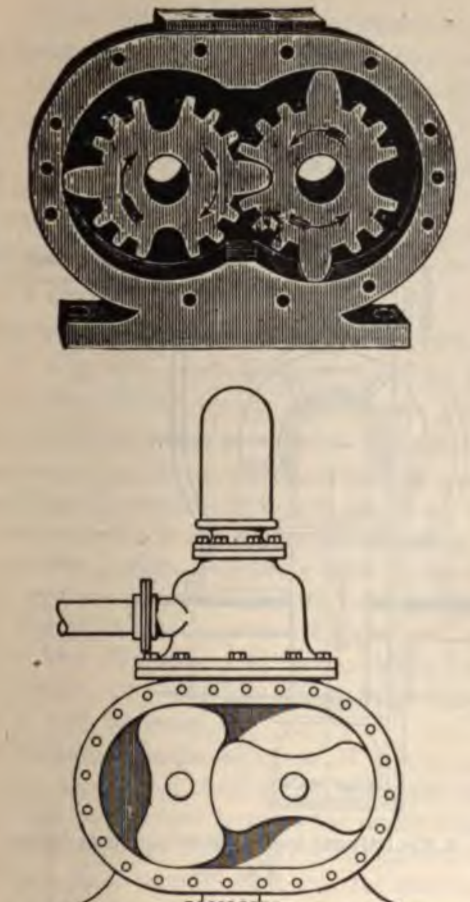
1. For what purpose is the pump to be used?

2. What is the maximum number of gallons to be pumped per hour?

3. What is the liquid to be pumped? If water, is it hot or cold, clear or gritty, fresh, salt, alkaline or acidulous?

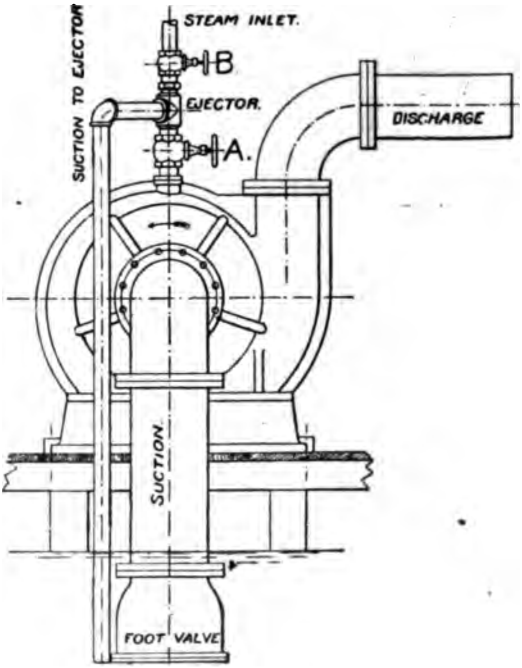
4. What distance, vertically and horizontally, will fluid be drawn on suction side of pump?

5. To what distance vertically and horizontally, or against what pressure per square inch is the fluid to be forced?



A Rotary Pump.

Fig. 198.



A Centrifugal Pump, Showing Installation.
Fig. 199.

6. What will be the steam pressure at pump? Give lowest steam pressure that pump may have to work with.

7. How many hours per day is the pump to operate, or is it to run continuously?

8. If the pump is to be connected to pipes already placed, give the diameters of the pipes, also number of bends and elbows.

Compound Pumps.—In Fig. 215 is shown a sectional view of a compound duplex steam pump.

Rotary Pumps.—The action of these pumps, as shown in Fig. 198, depends upon the force given to the water, or other liquid, by the action upon it of two tooth wheels, which are made to revolve in an enclosed chamber, each tooth of these wheels acting as a small piston, and pushing the water or liquid ahead of it. The flat faces of these wheels should be made a snug fit between them and the casing, and the edges of the teeth also a good fit against the sides of the casing. These pumps occupy but little space, and are light and inexpensive, but are of low efficiency. They are chiefly used to pump heavy liquids, or water holding in suspension large masses of soft material.

Centrifugal Pumps.—Pumps of this type, as shown in Fig. 199, depend for their action upon the pressure produced by the centrifugal force of the water rotated rapidly by the vanes of the pump. As it is the centrifugal force upon which these pumps must rely for moving the water or other liquid, they are designated by that name.

These pumps are only efficient when working under low lifts, being limited to a lift not exceeding 40 feet. They are well adapted for pumping large volumes of dirty water or sewerage, and are therefore much used for sewerage pumping and dredging.

CHAPTER XXII.

TYPES AND DESCRIPTIONS OF STEAM PUMPS.

Single Cylinder Direct Acting Steam Pumps.—The **single cylinder** pump is preferred by many persons as delivering for a given capacity more water, with less steam used than possible with the **duplex** pump. This is due to the fact that the friction of the single cylinder pump is much less than for the duplex pump. For instance, if the stuffing boxes of one side of a duplex pump are tightened more than on the opposite side, the piston on the tight side will move more slowly, as the valve on that side is actuated by the more rapidly moving piston on the other side, thereby considerably shortening the stroke, which reduces the volume of water delivered corresponding to a given number of strokes per minute.

This is never the case in a single cylinder pump, as its piston never starts on the return stroke until it has traveled the **full length** of its stroke in either direction, since the admission of steam is controlled by one and the same motion of all the reciprocating parts which it operates.

Better economy is also claimed for the single cylinder pump owing to the smaller **radiating surface** for a given capacity, and to the much smaller **clearing space** in the steam end. While the single cylinder pump has only two main ports leading to the cylinder, the duplex pump has four main ports in each cylinder. Of course, this greatly **increases** the amount of clearance, which means a proportionately greater waste of steam.

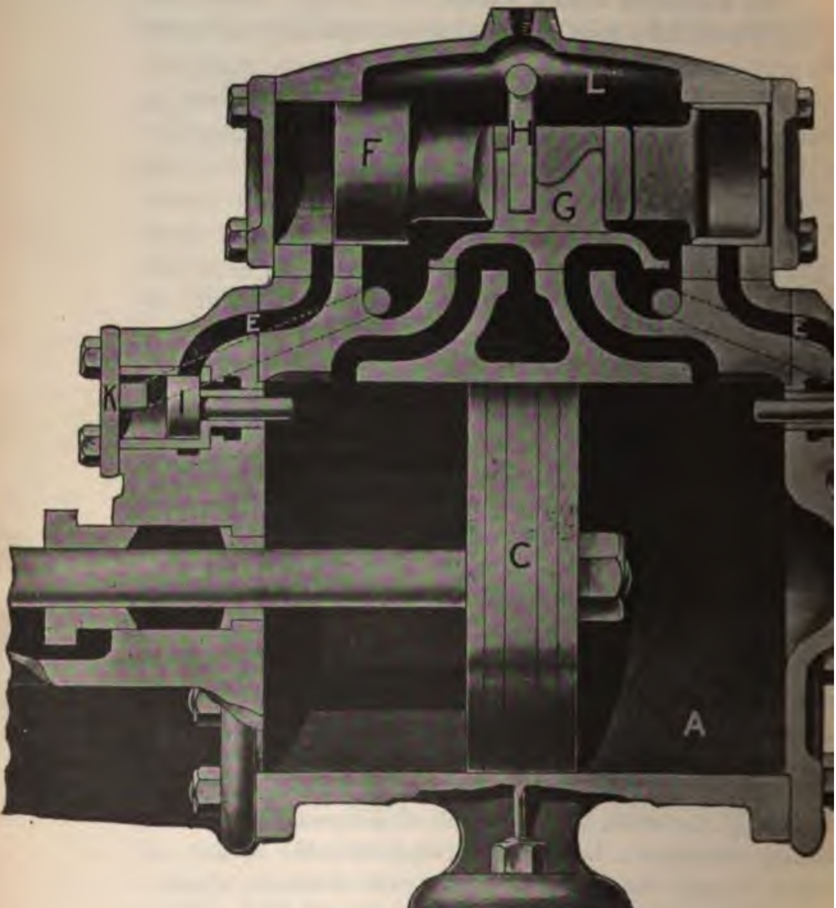
The adjustment and readjustment of the valve is also almost wholly eliminated in the single cylinder pump.

The following is a concise description of the several leading types of the single cylinder direct acting steam pumps, which are in most general use in this country.

The Cameron Steam Pump.—All single, direct acting pumps make use of an auxiliary plunger to carry the main slide valve, which gives steam to the main piston. By means of various devices steam pressure is made to drive this auxiliary plunger backward and forward. In the **Cameron** pump, shown in Fig. 200, the plunger is reversed by means of two plain tappet valves, and the entire mechanism thus consists of four stout pieces only, all working in direct line with the main piston. Simple and without delicate parts, it is the only inside valve gear that is absolutely reliable.

Explanation.—A is the steam cylinder; C, the piston; L, the steam chest; F, the chest plunger, the right hand end of which is shown in section; G, the slide valve; H, a lever, by means of which the steam chest plunger F may be reversed by hand when expedient; II are reversing valves; KK are the reversing valve chamber bonnets, and EE are exhaust ports leading from the ends of steam chest direct to the main exhaust and closed by the reversing valves II.

Operation.—C, the piston, is driven by steam admitted under the slide valve G, which, as it is shifted backward and forward, alternately connects opposite ends of the cylinder A with the live steam pipe and exhaust. This slide valve G is shifted by the auxiliary plunger F; F is hollow at the ends, which are filled with steam, and this, issuing through a hole in each end, fills the spaces between it and the heads of the steam chest in which it works. Pressure being equal at each end, this plunger F, under ordinary conditions, is balanced and motionless; but when the main piston C has traveled far enough to strike and open the reverse valve I, the steam exhausts through the port E from behind that end of the plunger



The Cameron Direct Acting Steam Pump.
Fig. 200.

F, which immediately shifts accordingly and carries with it the slide valve G, thus reversing the pump. No matter how fast the piston may be traveling, it must instantly reverse on touching the valve I. In its movement the plunger F acts as a slide valve to close the port E, and is cushioned on the confined steam between the ports and steam chest cover. The reverse valves H are closed as soon as the piston C leaves them by a constant pressure of steam behind them conveyed direct from steam chest through the ports shown by dotted lines.

The Marsh Direct Acting Steam Pump.—In Fig. 301 is shown a sectional view of the interior construction of the larger sizes of **Marsh** pumps.

The steam entering the chest is passing to the left, through the annular opening formed between the reduced neck of the valve and the bore of the first chest wall. It is thus projected against the inside surface of the valve head before escaping through the port and passing to the cylinder.

Both the pressure and impulse due to velocity, acting on the valve head, operate to close or restrict the admission portage at the annulus, by forcing the valve to the left, or in the direction of the current. On reaching the cylinder, and driving the piston toward the right, the reactive effect of the cylinder steam upon the opposite side of the valve head, entering the outer end of the chest chamber, is pressing the valve toward the right—a movement which would give the admission more portage, and deliver more steam to the cylinder.

The valve then holds a position depending upon the relative strength of the two forces which tend to move it in opposite directions—**admission steam,** which

3. The trip tube stuffing box in steam piston must be repacked occasionally.

The Burnham Direct Acting Steam Pump.—The following is a short description of the Burnham Steam Valve and its operation, as illustrated by the sectional views, shown in Fig. 202.

Fig. 1 is a top view of the pump, showing auxiliary valve and chest in section.

Fig. 2 shows a vertical section through the pump.

Live steam enters steam chest at B and is admitted to the cylinder, alternately, through port E and port F.

At the beginning of the stroke, port E is covered by the piston, as shown in cut; a pre-admission port G is provided, which admits only enough steam to give the piston an easy start; but when the steam piston has moved far enough to uncover the port E, it receives the full steam pressure and moves at its normal speed until it covers the port F, when it traps the remaining exhaust steam in the end of the cylinder, and thus forms a cushion, giving the piston rod an easy stop.

The gear is positive in action and is operated by a slotted lever A, moved by a roller attached to the piston rod. This lever A, alternately, moves blocks K and L, both of which are fastened to valve stem T, which in turn moves auxiliary valve H (Fig. 1) in the direction opposite to the motion of the piston.

At the end of the stroke, the auxiliary valve H will be moved to the left far enough to open port P to exhaust through R, at the same time admitting live steam through port C. This causes the chest piston M to move instantly, carrying main valve D with it, and reversing the motion of the pump.

The chest piston has a pair of preadmission ports similar to those described above for the main piston, and

tends to **close** the valve, and **cylinder steam,** which tends to open the valve wider. **This constitutes** the **governing element.**

Operation.—Having now explained that the steam is always in a perfectly balanced position, next will be considered how it is reversed at the end of the stroke.

The steam piston consists, as shown, of a spool form, each head of which is provided with a metal packing ring; the interior space forming a reservoir for live steam, which is supplied from the upper chamber of the chest, above the valve, following the passage indicated by dotted lines to the central cap in cylinder cover, through attached tube and hollow piston rod.

This pressure is used only for the purpose of "tripping" or reversing the valve, by admitting steam alternately against the outer surface of the valve heads, through the connecting passages near each end of the steam cylinder.

Caution.—To engineers in charge of Marsh pumps, it is deemed necessary to call attention to the following points:

1. The gasket packing between the steam chest and cylinder must be patterned from the planed surface on top of cylinder (not lower part of chest), carefully duplicating all holes, and making certain that the drilled ports at each end are unobstructed at point of register with corresponding holes in chest, either by dirt or packing.

2. The cylinder cover must be so placed, when bolting to cylinder, that the continuation of passage shown in dotted lines, carrying the trip supply steam to piston, shall register in head and cylinder, and a thin gasket packing be placed under the cover, with hole to connect the passages.

are for the purpose of giving a steam cushion to insure quiet action.

Blocks K and L are independently adjustable on rod T, enabling the engineer to make the piston run as close to the heads as he desires, and to make adjustment to compensate for wear.

The advantages of this valve gear are: A momentary pause of the piston at the end of each stroke, causing the water valves to seat quietly without shock or jar; a slow initial movement of the piston, whereby the water columns are started gradually, relieving the pump and piping of undue strains; a steam pressure on the main steam piston proportioned to the amount of work that it has to do; and immunity from damage in case of accident.

Directions to Set Valve.—While testing the Burnham pump at the factory, the valve is adjusted to give an ample amount of clearance to the steam piston, and all pumps should be readjusted after they have been in operation for a time, to suit the conditions and duties required.

You will find on tie rod (see cut), upon which moves the piston rod guide, a mark at each end, indicating the extreme travel of the piston.

If you find that the pump does not run as close to the mark as practical, loosen the set screw in cam block on the opposite side of the actuating lever from which you wish to lengthen the stroke, and move the cam block away from the point of contact of actuating lever.

This will allow the piston to move farther before opening the valve.

You will find that by moving this cam block 1-16 of an inch, it makes quite a perceptible difference in the

ton travel, according to the size of pump to be adsted.

If pump should travel too close to the marks, which ould cause it to hesitate and stop at the end of stroke, ou should move these cam blocks toward the point of ntact of actuating lever.

Always move the cam blocks on the opposite side f lever from which you wish to change the stroke.

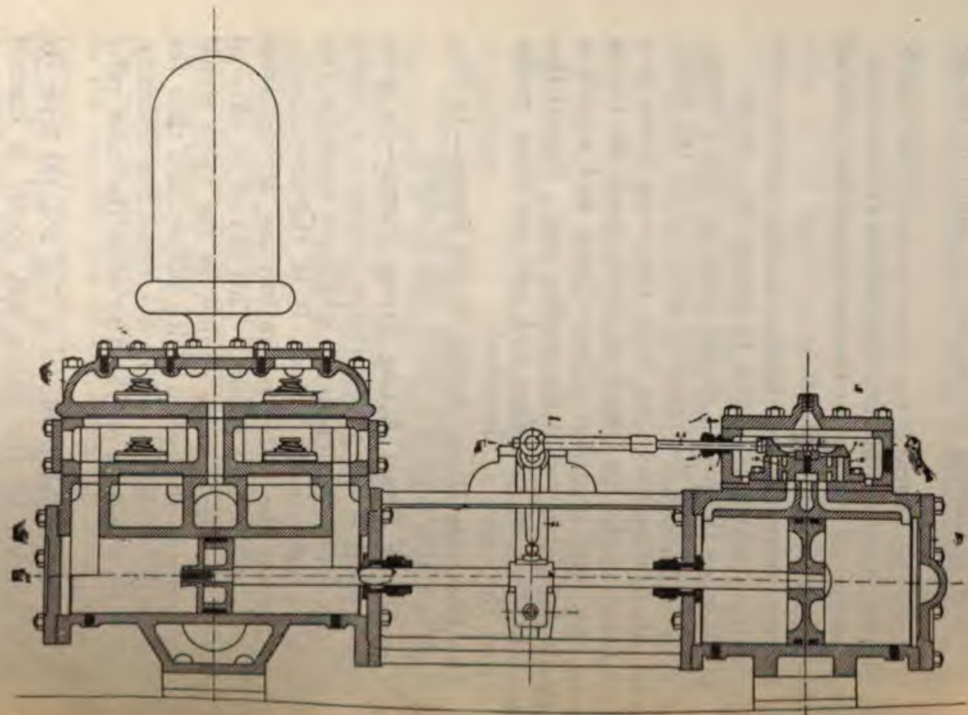
In all cases the piston should make as long a stroke s possible and give the required speed to do the work.

In all pumps made up with cast iron yokes not owing the marks for length of stroke, push the piston one end until it strikes cylinder head, and scratch a ark on the piston rod at the stuffing box. Repeat this me operation on the other end, and use these marks adjust the valve as described.

The Blakeslee Direct Acting Steam Pump.—In Fig. 3 is shown this type of a direct steam pump.

The Deane Direct Acting Steam Pump.—In none the so-called direct acting steam pumps is a rotary otion developed by means of which an eccentric can made to operate the valve. It is, therefore, necesry to reverse the piston by an impulse derived from self at the end of each stroke. This cannot be effected an ordinary single valve engine, as the valve would e moved only to the center of its motion, and then the hole machine would stop. To overcome this difficulty, small steam piston is provided to move the main valve f the engine.

In the Deane pump, shown in Fig. 204, the lever 90, which is carried by the piston rod, comes in contact with the tappet when near the end of its motion, and, y means of the valve rod 24, moves the small slide alve which operates the supplemental piston 9. The



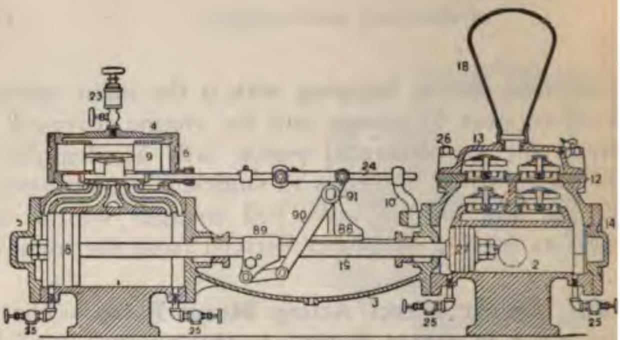
supplemental piston, carrying with it the main valve, is thus driven over by steam, and the engine reversed. If, however, the supplemental piston fails accidentally to be moved, or to be moved with sufficient promptness by steam, the lug on the valve rod engages with it and compels its motion by power derived from the main engine.

The Hooker Direct Acting Steam Pump.—The essential point in **steam pumps,** is the movement of the **steam valves,** which control the admission and release of the steam to and from the **steam cylinder,** for on this depends the correct and even length of the stroke of **pumps** and economical distribution of steam for the required duty.

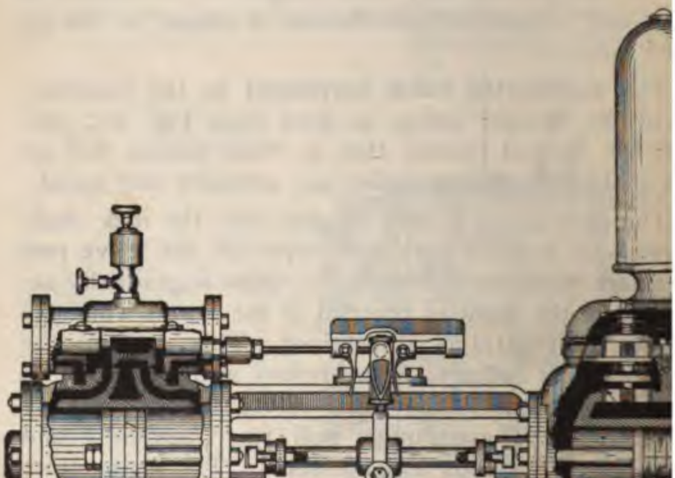
The **accelerated valve movement** in the construction of the Hooker pump, as seen from Fig. 205, produces the desired results, that is, their pistons will always make **full strokes** under any pressure and speed.

The cam which is cast integral with the rock shaft, is always in contact with one wiper on the **valve rod.** The **steam valve** starts slowly, its speed is gradually accelerated to the point of reversal of the piston when the maximum valve travel is attained. This compels the pump to make full and even strokes without resort to tappet connections to move the valve, thereby avoiding all pounding. These pumps will run noiselessly and smoothly at all speeds and pressures. The main **steam valve** is cushioned on compressed live steam; it reverses instantly and without noise or shock.

The Knowles Direct Acting Steam Pump.—The prime advantage of this pump, shown in Fig. 206, is its absolute freedom from what is termed a **"dead center."** This feature is secured by a very simple and ingenious mechanical arrangement, i. e., by the use of an auxiliary



The Deane Direct Acting Steam Pump.
Fig. 204.



The Hooker Direct Acting Steam Pump.
Fig. 205.

piston which works in the steam chest and drives the main valve. This auxiliary or "chest piston," as it is called, is driven backward and forward by the pressure of steam, carrying with it the main valve, which valve, in turn, gives steam to the main steam piston that operates the pump This main valve is a plain slide valve of the B form, working on a flat seat.

The chest piston is slightly rotated by the valve motion; this rotative movement places the small steam ports (which are located in the under side of the said chest piston) in proper contact with corresponding ports cut in the steam chest. The steam entering through the port at one end and filling the space between the chest piston and the head, drives the said piston to the end of its stroke and, as before mentioned, carries the main slide valve with it. When the chest piston has traveled a certain distance, a port on the opposite end is uncovered and steam there enters, stopping its further travel by giving it the necessary cushion. In other words, when the rotative motion is given to the auxiliary or valve driving piston by the mechanism outside, it opens the port to steam admission on one end, and at the same time opens the port on the other end to the exhaust. Thus instant and **positive** motion is secured with but few working parts. There is no point in the stroke at which either the chest piston or the main piston is not open to direct steam pressure. Hence the immunity from any dead point whatsoever.

Operation.—The piston rod, with its tappet arm, moves backward and forward from the impulse given by the steam piston. At the lower part of this tappet arm is attached a stud or bolt on which there is a friction roller. This friction roller, with its bolt and nut, can be lowered or raised, when it is desired, to adjust

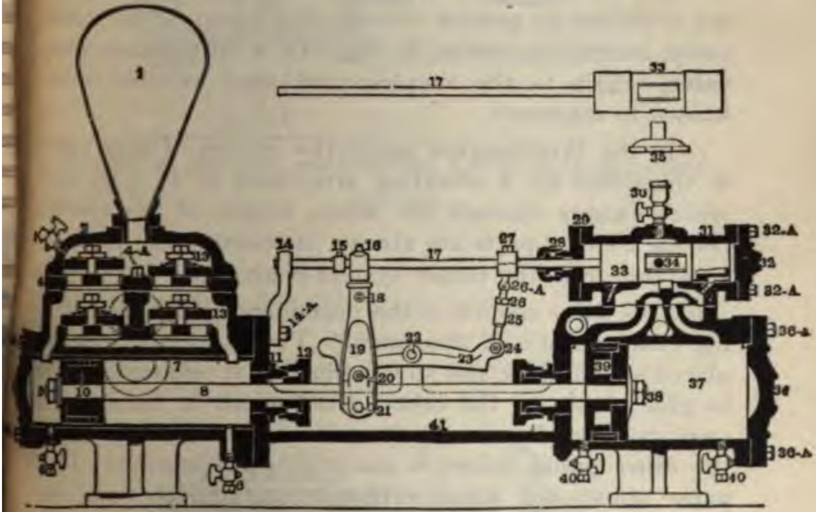
the pump for a longer or shorter stroke. This roller, coming in contact with the "rocker bar" at the end of each stroke, operates the latter. The motion given the "rocker bar" is transmitted to the valve rod by means of the connection between, causing the valve rod to partially rotate. This action, as mentioned above, operates the chest piston, which carries with it the main slide valve. The said valve giving steam to the main piston, the operation of the pump is complete and continuous. The upper end of the tappet arm does not come in contact with the tappets on the valve rod, except the steam pressure from any cause should fail to move the chest piston, in which case the tappet arm moves it mechanically. This makes the pump absolutely positive.

Directions.—Should a pump run longer stroke one way than the other, simply lengthen or shorten the rocker connection (Part 25) so that rocker bar (Part 23) will touch rocker roller (20) equally distant from center (22).

2. Should a pump hesitate in making its return stroke, it is because rocker roller (20) is too low and does not come in contact with the rocker bar (23) soon enough. To raise it, take out rocker roller stud (20-A), give the set screw in this stud a sufficient downward turn, and the stud with its roller may at once be raised to proper height.

3. Should valve rod (17) ever have a tendency to tremble, slightly tighten up the valve rod stuffing box nut (28). When the valve motion is properly adjusted, tappet tip (16) should not quite touch collar (15) and clamp (27). Rocker roller (20), coming in contact with rocker bar (23) will reverse the stroke.

4. The water piston is adjustable by means of segments that can be seen by taking off the follower, and



The Knowles Direct Acting Steam Pump.

Fig. 206.

the packing quickly set out to always insure perfect suction and at the same time not be so tight as to bind.

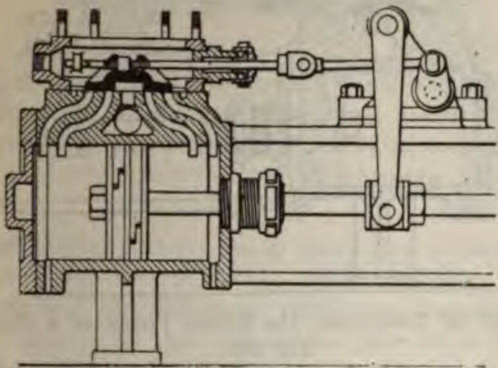
Construction of Duplex Steam Pumps.—In Fig. 211 is shown a sectional view of the ordinary construction of a duplex steam pump.

The Worthington Duplex Steam Pump.—In Fig. 214 is shown an outside view of this pump. The steam valve, as may be seen at E, Fig. 211, is an ordinary slide **valve**, which is the simplest and most reliable valve known to engineers.

In the Worthington pump the motion of this valve is controlled by a vibrating arm, seen at F, Fig. 211, which swings through the whole length of the stroke. As the moving parts are always in contact, the blow inseparable from the tappet system is avoided.

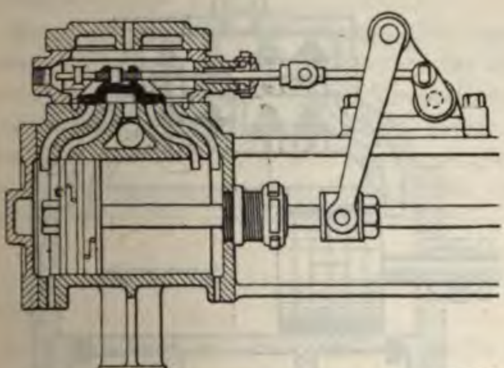
This valve motion is the prominent and distinguishing characteristic of this pump. Two steam pumps are placed side by side and so combined that one piston acts to give steam to the other, after which it finishes its own stroke and waits for its valve to be acted upon by the other pump before it can renew its motion. This pause allows the water valves to seat quietly, and removes any harshness of motion. As one or the other of the steam valves is always open, there is no dead point, and therefore the pump is always ready to start when the steam is admitted. The same type of steam cylinder and valve motion is furnished with pumps of either the plunger-and-ring pattern or the piston pattern.

In the plunger-and-ring pattern there is a double acting plunger working through a deep metallic ring bored to fit accurately the plunger. The plunger is located some inches above the suction valves, leaving a subsiding chamber, into which any foreign substance may fall out of the way of the wearing surfaces. Both



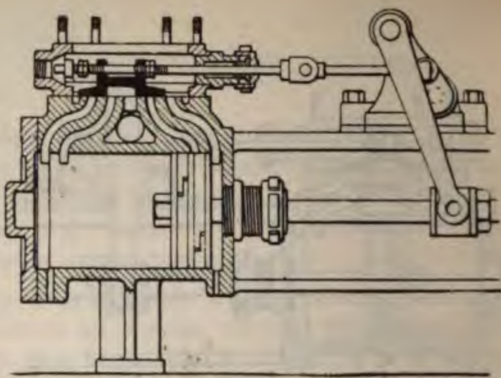
Position of the Gear when setting Valves of Duplex Pump.

Fig. 207.

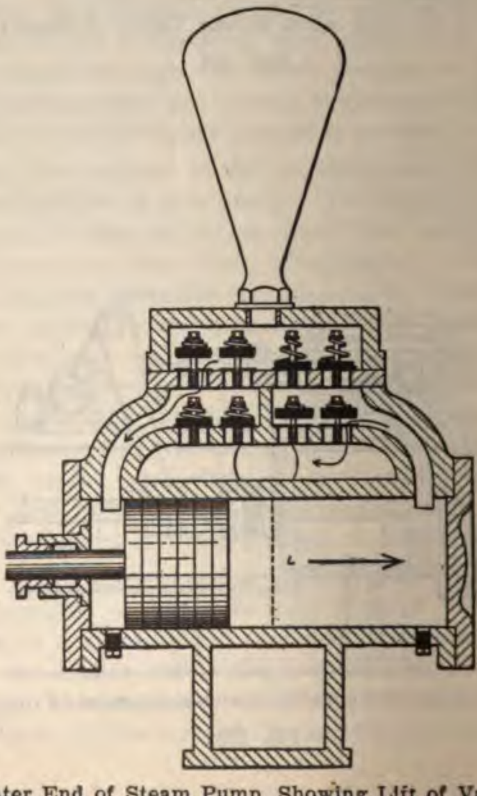


oper Position of the Valve at commencement of the Stroke.

Fig. 208.



Method of Cushioning the Steam Piston of a Pump.
Fig. 209.



Water End of Steam Pump, Showing Lift of Valves.
Fig. 210.

the plunger and ring can be quickly taken out and either refitted or, when necessary, renewed at small cost. The valves consist of small discs of rubber, or other suitable material, and are easily accessible through convenient hand-holes.

In the piston pattern pump there is a packed water piston, working in a brass lined cylinder. Both the suction and the discharge valves are located above the water pistons, so that the pistons may be at all times submerged. The valve areas and water passages are large, and special care is taken to have all the internal parts easily accessible for inspection and repairs. This pattern is recommended where the liquid to be pumped contains small quantities of grit or foreign material, or where there is an unusually long or high suction lift. In both arrangements all the moving parts are made to gauge, and may be readily removed.

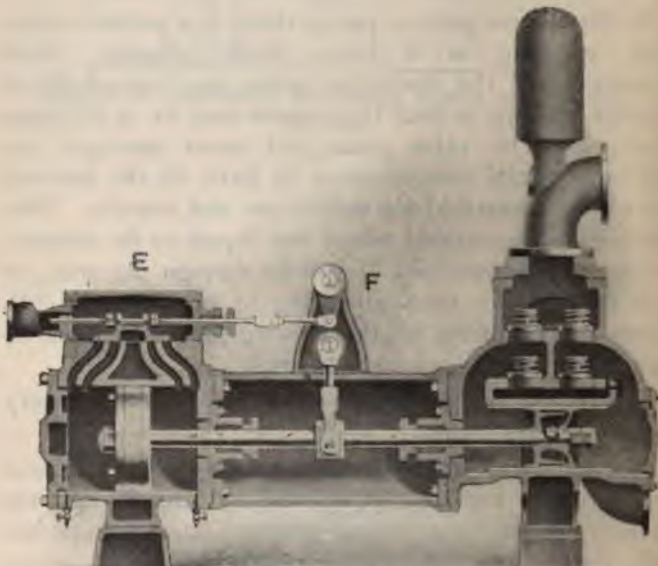
In Fig. 212 is shown an exterior view of the ordinary type of a duplex pump.

The Snow Duplex Steam Pump.—The sectional view, shown in Fig. 213, serves to illustrate the extreme simplicity of the Snow steam pump. These pumps are of the duplex pattern, consisting of two direct acting engines and two double acting pumps, so coupled that the steam piston of one actuates, through the medium of the vertical lever, the steam distribution valve of the other.

The advantages of the Snow duplex valve motion are as follows:

1st. It is so simple that its operation can be understood by anybody, whether a mechanic or not.

2d. It is reliable, and will continue to distribute the steam and operate the pump under even the most extreme conditions of wear and abuse.



Sectional View of a Duplex Steam Pump.
Fig. 211.

3d. It can never place the valves in such a position that all the ports are covered by them at the same time; hence, the pump can always be started by simply turning on steam, and it can never stall.

Explanation.—Assume that the pistons of No. 1 side have completed the stroke. They have then moved the slide valve of No. 2 side to one extreme position and opened full the admission port to one end and the exhaust port from the other end of No. 2 cylinder; hence the No. 2 pistons are making their stroke and are gradually reversing the slide valve of No. 1 side. When the No. 2 pistons have completed about two-thirds of their stroke, they have moved the slide valve of No. 1 side so that it has just begun to open the No. 1 ports, to start the No. 1 pistons on their return stroke. No. 2 pistons continue to move to complete the stroke, and to open the No. 1 ports, and by the time they have completed about five-sixths of their stroke the No. 1 pistons have gotten under way on their return stroke, and the No. 2 steam piston has covered the exhaust port through which steam was being exhausted and is slowing down under the influence of the cushion or dash relief valve. This valve intercepts a small port connecting the steam port with the exhaust port at each end of each steam cylinder, and through which the imprisoned exhaust steam has to pass to permit the pistons to complete their stroke. This they do, gradually slowing down and finally coming to rest at the end of the stroke, having moved the slide valve of No. 1 side to its extreme position, thus opening the No. 1 ports wide. By this time the No. 1 pistons have completed about one-half of their stroke and are reversing the slide valve of No. 2 side, while the No. 2 pistons are at rest; and when the No. 1 pistons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have completed about five-sixths of their stroke, and are slowing down under the influence of the cushion valve, the No. 2 pistons are under way again on their return stroke, while the No. 1 pistons gradually slow down and come to rest at the end of their stroke.

The effect of the slowing down and the pause at the end of the stroke can be readily seen from the following: While the pump piston, or plunger, is moving at its highest velocity, the suction valves on one end and the delivery valves on the other end are raised to the highest position from their seats; but while the piston, or plunger, slows down and pauses at the end of the stroke, they seat gently, so that by the time the return stroke is begun the valves have seated and the opening of the other valve is cushioned by the valve springs.

The result is the entire absence of valve hammer, so common in quick reversal pumps.

It causes the pump to deliver a steady and uniform flow of water, thus preventing any water hammer in the pumps or pipes.

RTS OF THE SNOW PISTON PATTERN STEA

ead
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28 Rock Shaft Key or Pin
29 Steam Piston Body
33 Steam Piston Ring
34 Steam Piston Nut
35 Piston Rod
36 Piston Rod Stuffing Box
37 Piston Rod Gland
37½ Piston Rod Stuffing Box Follower

61 Valve Plate
62 Air and Drain Cocks
63 Piston Pump Cylinder Head
65 Pump Piston Body
66 Pump Piston Follower
75 Driven Lining

CHAPTER XXIII.

QUESTIONS AND ANSWERS ON PUMPS.

Q. What is a pump?

A. A mechanical device for transferring or circu-lating fluids.

Q. What are the two common methods of operat-ing pumps, and how designated?

A. By direct connection with the steam cylinder, alled direct acting pumps; by belting or gearing, called elted pumps.

Q. How are boiler feed pumps usually operated?

A. By direct connection to steam cylinder, that is, y direct acting steam pumps.

Q. How is the water piston mounted in a direct cting pump?

A. On the same rod as the steam piston.

Q. How is a single direct acting pump carried over he dead center?

A. By an auxiliary valve gear in connection with he main valve gear.

Q. Is a duplex pump a direct acting pump?

A. Yes.

Q. Is a single cylinder pump a direct acting pump?

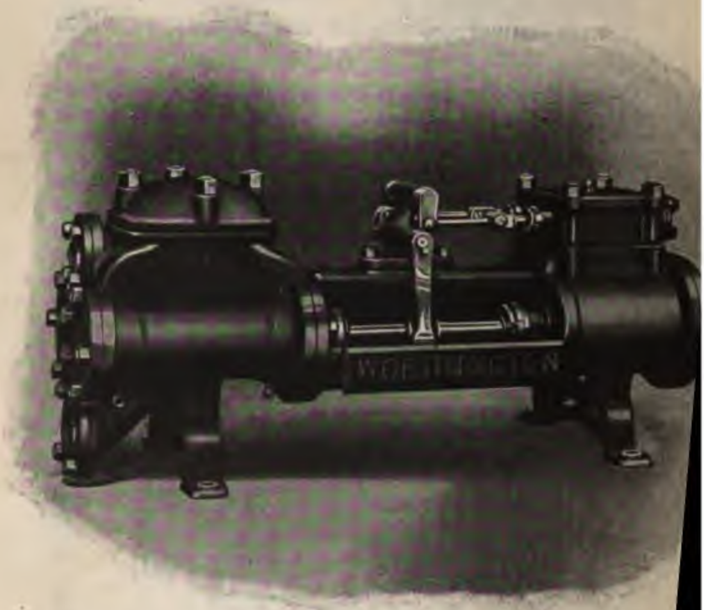
A. Yes, it differing chiefly from a **duplex** pump in he operation of its valve gear.

Q. How many valves has a single acting plunger ump?

A. Two valves, one for receiving and the other or discharging.

Q. How many valves has the double acting pump?

A. Four valves, two for receiving and two for dis-harging.



The Worthington Duplex Steam Pump.

Fig. 214.

Q. How many valves do large pumps often have n the water cylinder?

A. They often have as many as sixteen and frequently thirty-two small valves on the water cylinder.

Q. Would it not be better to have a few large alves instead of so many small valves on this cylinder?

A. No, because the small valves do not require as uch lift as the larger ones, consequently at each stroke f the pump they do not lose the quantity of water that ould be lost with the larger valves.

Q. Which should have a larger area, the steam pisn or the water piston of a pump?

A. The steam piston, otherwise the pressure on e water piston would equal the pressure on the steam ston and the pump would refuse to work.

Q. How much larger area should the steam piston ve than the water piston?

A. About two and three-fourths times the area of e water piston.

Q. How would you therefore find the area of the eam piston?

A. Multiply the area of the water piston by 2.75.

Q. How do you find the horse power necessary to ımp water to a given height?

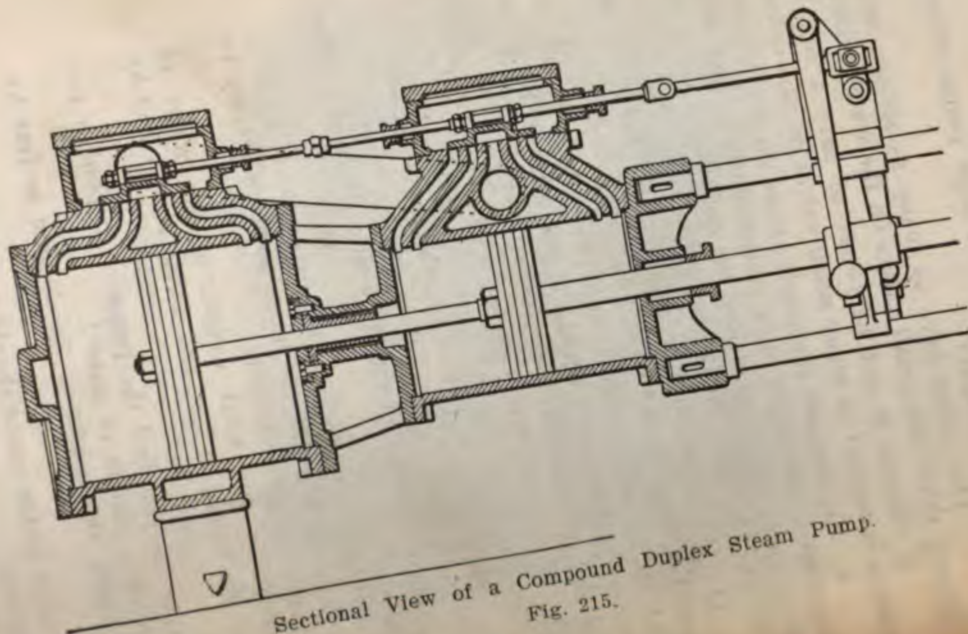
A. Multiply the total weight of the water in ounds by the height in feet, and divide the product by 3,000.

Q. How do you find the pressure in pounds per quare inch of a column of water?

A. Multiply the height of the column in feet by 434.

Q. At what piston speed should an ordinary boiler feed pump be run?

A. About fifty or sixty feet per minute.



Sectional View of a Compound Duplex Steam Pump.

Fig. 215.

Q. Why are the valves of duplex pumps made without lap?

A. In order to avoid the danger of sticking upon the centers.

Q. What precautions should be taken in leaving pumps in cold weather?

A. All the water should be drained in order to avoid freezing. Therefore, the drip plugs and cocks which are provided for the purpose of draining the pump, should be opened.

Q. How would you choose the proper size of a boiler feed pump for a given boiler?

A. Multiply the horse power of the boiler by 34½, which will give the number of pounds of water evaporated by the boiler per hour from and at 212 degrees. Divide this result by 8.35, which gives the number of gallons. Then choose a pump capable of supplying double this quantity, so that it will be large enough even when the boiler is being forced to its utmost.

Q. How do you designate the size of a pump?

A. By giving the diameter in inches of the steam end, by that of the water end, by the length of the stroke, in the order named.

Q. Give an example?

A. A pump 8"x6"x10," is a pump having an 8-inch steam end, 6-inch water end and a 10-inch stroke.

Q. In the Cameron pumps, how does the steam escape from behind the chest plunger into the main exhaust?

A. Through the ports shown just above and below the reversing valves.

Q. In Fig. 210 does the arrow indicate the right direction of the piston, and at what point will the piston be in stroke when the valves seat?

A. Yes, for in high speed pumps the valves will not seat before the piston has reached about one-third of return stroke. This is due to the pump slippage and time for valves to seat.

CHAPTER XXIV.

ELECTRICITY AND MAGNETISM.

Definition.—What is electricity is not known. It is invisible and impalpable. Our knowledge of it is confined to its **generation** and application, but that alone is of the greatest moment to the engineer and student, for without such knowledge no stationary engineer should hold a first-class license, permitting him to operate a modern steam plant.

Electricity is now so universally used, that in addition to the many growing demands upon the modern steam engineer, is the necessity for a thorough knowledge of the operation of electrical generators and motors, and a thorough understanding of the **principles** upon which they operate.

Electricity.—The name **electricity** is derived from the Greek word **electron,** which means **amber.** It was discovered many centuries ago, that amber when **rubbed** possessed the curious property of attracting light bodies. This manifestation of attraction in the amber or electron, was believed by the Greeks to be due to a spirit that dwelt within the amber, and which was aroused by the warmth generated by the friction of the rubbing.

Such was the discovery of the wonderfully subtle force that is revolutionizing the world, and which requires every student or engineer who hopes to make success in any branch of the engineering field to master its principles and operation in order to succeed in his particular work.

Static Electricity.—This is a term employed to designate electricity produced by **friction.** When static electricity is discharged, it produces more or less a current which shows itself by the passage of a spark, but

is only of short duration, and is of no practical value. It is electricity **at rest**, and is used in distinction to electricity **in motion**, or **dynamic** electricity, which is of far more importance, and which will therefore be chiefly considered in this work.

Classification.—The subject of electricity is divided into the following classes, viz.:

(1) Static electricity, or electricity **at rest.**

(2) Current electricity, or electricity **in motion.**

(3) Magnetism, or electricity **in rotation.**

(4) Electricity in vibration or **radiation.**

Generation.—The usual method of generating statical electricity, is by the use of what is known as the **plate machine.**

Plate Machine.—This machine consists of a circular plate of glass that is mounted upon a shaft made to turn by means of a crank and handle. Pressed to either side of the glass, at the top and bottom, is a rubber made of cloth, felt or soft leather.

At right angles to the rubbers on the circle of the plate, there is a frame from which a number of sharp points project which are brought so that they almost touch the plate. These points and the frame to which they are attached, are connected by a good conductor to what is known as the prime conductor.

Operation.—The operation of such a machine is exceedingly simple. The plate is caused to revolve, and the **frictional** action of the rubbers upon it, charges it with electricity. As the successive portions of the glass plate pass beneath the points, the electrical charge is drawn off and carried by them to the prime conductor, from which it can be drawn in turn to the Leyden jar wherein it is stored.

Current or Dynamic Electricity.—Current electricity

may be defined as a quantity of electricity which passe through a conductor, or is electricity in **motion.** Th production of **all** electricity is the transforming of or form of energy into another, usually by mechanic means; and in this form of electricity, the device for e fecting such transformation of **mechanical** into **electric** energy, is called a **generator** or **dynamo.**

An electrical motor, on the contrary, is a device f changing **electrical** into **mechanical** energy.

Manifestations.—An electric current manifests self by the **heating** of the wire or the conductor throug which it passes, or, by causing a **magnetic field** aroun the wire or conductor, or lastly, by causing **chemica changes** in a **liquid** through which it is made to pass.

All these manifestations indicate the character o useful work capable of being performed by an electri current. First, the **heat** caused by the resistance of th conductor through which the current passes, is made t generate light and heat. Second, the **magnetic fiel** around the wire or conductor is used to operate all char acter of electrical machines and motors and also mak high voltage currents safe and practical by the use o transformers. Third, the **chemical changes** brough about in the liquid by the passage through it of the cur rent, is used for the storage of electricity to be late used, as needed.

Primary Batteries.—The simplest method of gene ating electricity for practical use, is by an electrical ba tery.

Principle.—If a plate of metal is placed in a liqu called an **electrolyte,** there is set up a chemical actic which produces **different** conditions of energy betwe the metal and the liquid, and the metal either takes lower or a higher electrical potential than the liquid

which it is immersed, according to the nature of the metal and the liquid.

Cell.—Now, if **two** different metals or elements are placed in the electrolyte, there is a **difference** of potential or energy at once produced between these two plates or elements, and if we should join them by a wire outside of the electrolyte or liquid, a current of electricity would pass over this wire from the metal most acted upon by the electrolyte to the one least acted upon by it.

The two metals or elements and the electrolyte compose what is known as a **simple electrical cell,** and such an apparatus for developing a continuous current of electricity, is named from its discoverers, a simple voltaic or galvanic cell.

Such a cell consists essentially of a vessel containing saline or acidulated water in which are submerged two plates of **dis-similar** metals, or one metal and a metaoid.

Action of a Simple Cell.—The action of a simple electrical cell is as follows: If in a glass jar partly filled with water, a little sulphuric or other dilute acid is added, and a clean strip of zinc and one of copper is placed, a chemical action will at once set up from the action of the acid on the zinc plate, producing a difference of electrical potential between the two plates, causing the current to flow from the one of higher potential to the one of less potential. If now the two electrodes are connected by a wire, there will be a **continuous** flow of electric current from the submerged end of the zinc plate through the liquid to the submerged end of the copper plate, and from the exposed end of the copper plate through the wire to the exposed end of the zinc plate.

Chemical Reaction.—The chemical reaction which

The hydrogen is given off as a gas from the l
ing the zinc sulphate in solution. This actio
as long as the current flows, which depend
amount of current flowing. The zinc gra
solves in the liquid, forming a solution of zi
This chemical action **ceases** when the liquid
contains any **acid**, or when the zinc has been
The spent liquid must then be replaced with
solution, and a new piece of zinc substitute

Polarization.—One great objection to
voltaic cell, is that the current produced
creases in strength after the circuit has been
a short time. This is due to the collection o
bubbles upon the surface of the copper plate,
vent the direct contact of the copper plate w
citing fluid, and in this way the **effective** a
plate is reduced, and proportionately, the s
the current. This also greatly increases the
sistance of the battery, thus decreasing the
current.

This accumulation of hydrogen bubble
polarization, and the cell is said to become **p**

Depolarization.—This consists of **reduc**

Current.—The electrical current produced is a continuous current, but of low voltage or pressure, and capable of doing but little useful work.

Battery.—To **increase** the strength of the current, several of these cells are joined together and are then called a **battery.** The strength of the battery is almost exactly proportional to the number of cells or elements of which it is composed.

These different cells can be connected together in three different ways in forming a battery; (1) by the series method, as shown in Fig. 236; (2) by the **parallel** or multiple **arc** method, also shown in Fig. 236, or, (3) in **multiple-series** method.

Series.—Cells are connected in **series** when the positive electrode of one cell is connected to the negative electrode of the second cell, and the positive electrode of the second cell is connected to the negative electrode of the third cell; continuing in this way for all the cells of the battery.

Parallel.—Cells are connected in parallel, or multiple-arc, when all the positive electrodes of the cells are connected to one main **positive** conductor, and all the negative electrodes are connected to one main **negative** conductor.

Multiple-Series.—Cells are connected in multiple-series when arranged in several groups, each group being composed of several cells connected in **series,** and then all the groups being connected in **parallel,** or multiple-arc.

While the **quantity** of the electricity which is generated is the same in each of the methods of connecting the cells, the **effects** resulting therefrom are quite different.

The series connection gives a **high** electrical pres-

sure or voltage, and a **small** volume of current, or amperage; while the parallel connection gives a **low** electrical pressure or voltage, and a **large** volume of current, or amperage.

The combination of these two methods of connecting cells, that is the multiple-series, gives a **higher** potential and a **stronger** current than is possible to obtain from any one cell of the groups of cells.

Construction of Cells.—Instead of using copper and zinc, other dis-similar substances can be used to produce an electrical current, and instead of using one electrolyte, two or more different electrolytes can be used. In this way a number of different cells for producing different electrical currents are constructed, each adapted to its special class of work.

In order to understand the action of an electrical current and its effects, the following **definitions** of the terms used in electrical work must be first fully understood.

Positive and Negative.—An electric charge developed upon glass by rubbing it with silk, has been termed for convenience a **positive** (+) charge, and that developed on resinous bodies by rubbing with flannel or fur, a **negative** (—) charge. By the word resinous, we mean electrification produced in resin by friction.

All electrical charges have **both** a negative and a positive charge in them, irrespective of the way the charge is produced. Electrified bodies with **similar charges** are repelled by each other, while electrified bodies with **dissimilar** charges are attracted by each other. Therefore, when two positive or two negative charges are brought together, they **repell** each other, but when a positive and negative charge are brought together, they **attract** each other.

Electric Series.—The following substances are arranged in such order that each receives a positive charge when rubbed or placed in contact with any of the bodies following it, and a **negative** charge when rubbed with any of those which precede it.

1. Fur.	9. Wood.
2. Flannel.	10. Metals.
3. Ivory.	11. Sealing-wax.
4. Crystals.	12. Resins.
5. Glass.	13. Sulphur.
6. Cotton.	14. Guttapercha.
7. Silk.	15. Guncotton.
8. The body.	

For instance, resins when rubbed with **fur** receives negative charge, but when rubbed with **sulphur** reves a **positive** charge.

Electrodes.—These are the plates of metal or other ɔstance immersed in the liquid. The zinc plate is led a **generating** electrode, and the other plate the **ıducting** electrode. In the simple cell thus described, zinc plate forms the **positive** element of the cell, ile the copper plate becomes the **negative** element.

Poles.—The poles of a battery are the parts of the ctrodes which project out of the liquid. They are tinguished from each other by the sign (+) for the sitive, and (—) for the negative. The term pole, or **minal** as it is often called, applies to the ends in any ctric circuit.

Electrolyte.—The electrolyte, or exciting fluid, is liquid which acts upon the plates or electrodes placed it, and produces a current between the two plates and wire joining them.

Electromotive Series.—The following list of ments compose what is called the **electromotive s**

1. Zinc.	8. Antimony.
2. Cadmium.	9. Copper.
3. Tin.	10. Silver.
4. Lead.	11. Gold.
5. Iron.	12. Platinum.
6. Nickel.	13. Graphite.
7. Bismuth.	

Any two of these metals produce a difference c tential when submerged in saline or acidulated v the one standing first on the list being the **positiv** ment or plate and the other the **negative.**

Classes.—Batteries are divided into two classe cording to the nature of work required to be don the electricity produced, being viz.: (1) **open** c batteries; (2) **closed** circuit batteries.

Open Circuit Battery.—This battery is so cons ted as to maintain a current that will not run dov exhaust itself when left on an open circuit

This is the most common form of battery, l used for telephones, electric bells, annunciators, etc

Leclanche Cell.—This is a typical **open circuit** and is constructed as follows.

Construction.—A rod of zinc forms the positiv ment. The negative element is contained in a **sep** jar of porous earthenware, and consists of a rod of bon surrounded with powdered carbon and peroxi manganese. The cell is almost filled with a soluti sal-ammoniac and water.

Upon closing the circuit outside the cell, the combines with the chlorine and the sal-ammoniac, an erates hydrogen gas and ammonia.

Iydrogen also appears at the carbon plate, the per- of manganese giving off its oxygen to combine the hydrogen to form water, H_2O. In this way the arizing takes place when the cell is not discharged gh too low a resistance.

ihould a **Leclanche** cell be worked too rapidly, it then be allowed to **rest** so as to permit the mangan- me to work, and the cell to be thus recuperated.

'he E. M. F. of a Leclanche cell is about 1.45 volts, its current varies from one ampere upwards, ac- ıg to the resistance of the cell.

'he resistance may be decreased by using a sheet ıc bent around the porous pot, or by making the ive element in a compressed form, so as to dis- with the use of a porous pot.

The Daniell Cell.—This is a typical **closed circuit** and is usually called a gravity cell, or a gravity ell cell, owing to the principle upon which it oper- being the difference of the **weight** in the two elec- tic liquids.

Construction.—A number of thin leaves of copper laced in the bottom of a jar, and sulphate of copper al poured over them.

A zinc block is hung from the top of the jar, so as ave a space of a few inches between it and the cop-

Water is then poured in the jar with a little sul- e of zinc, or a few drops of sulphuric acid, to hasten ıction.

The action of the cell rests upon the sulphate of er liberating its sulphuric acid, which is deposited opper on the copper plate. The sulphuric acid thus ated attacks the zinc, forming zinc sulphate, the us cup protects the zinc from the copper sulphate ion, and this solution prevents the hydrogen from

accumulating about the copper. The hydrogen unites chemically with the copper sulphate, forming sulphuric acid and free copper. The free copper is then deposited upon the outside copper portion. The chemical reaction is represented as follows:

$H_2 + CuSO_4 = H_2\ SO_4 + Cu.$

This cell is much used in telegraphy being very constant in its action, as no polarization can take place as long as the copper sulphate solution is **saturated.**

It is called a **gravity** cell owing to the copper sulphate solution remaining at the bottom of the jar, and the zinc sulphate solution at the top, the line of division being strongly marked.

The E. M. F. of a gravity Daniell's cell is about one volt, its current flow being from one to two amperes.

Primary and Secondary Cells.—A **primary cell** as seen above, is one in which the electric energy is produced by the chemical action on the plates of the cell, and which, when the solutions or plates are exhausted, are **not** restored to their original condition by the passage of an electric current. Almost all primary cells will act more or less perfectly as secondary or storage cells.

Circuit.—A circuit is a path composed of a conductor, which is usually copper wire, through which an electric current flows from a given point around through the conductor back again to the starting point. There is no **actual** flow of the current, for there is no transfer of matter or particles. A conductor carrying a current presents the same appearance as one not, the only manifestation being the heating of the conductor, should the capacity of the wire be too small for the current carried. The flow of the current is caused by the difference of potential, and the greater the amount of potential dif-

ference, the greater is said to be the **pressure or electromotive force,** usually written E. M. F., or voltage which causes the flow. The **strength** of the current flowing through the conductor depends directly upon the amount of this electromotive force, and also upon the amount of the resistance to the flow. If the circuit is short and composed of good conductors, the current will be much stronger than if it were long and composed of poor conductors.

Grounded Circuit.—A circuit in which the earth, or ground, forms part of the circuit is called a **grounded** circuit.

External Circuit.—The **external** circuit is that part of a circuit which is **outside** or external to the generator or other source of supply.

Internal Circuit.—The **internal** circuit is that part of a circuit which is included or within the generator, or other source of supply.

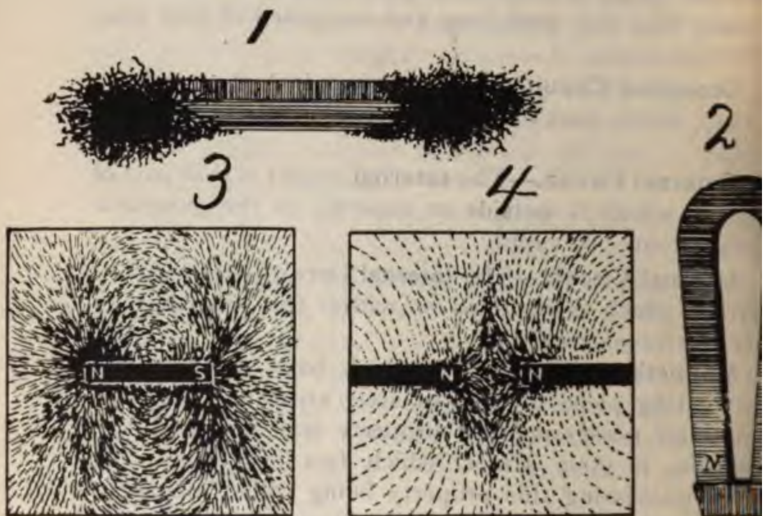
Magnetism.—Substances which have the property of attracting pieces of iron or steel are called **magnets.** A material possessing this property was first found at Magnesia, in Asia Minor, which fact led to all substances possessing this property being called **magnets.**

Natural Magnets.—The natural magnet is an oxide of iron, called **lodestone,** and is found widely distributed in different parts of the world.

Artificial Magnets.—When a bar of hard steel is rubbed with a lodestone, the steel will acquire some of the properties of the magnet, and can be used as a magnet as long as it retains those properties.

When such magnets retain their magnetism for a long time, they are then called **permanent** magnets.

In Fig. 216 (2) is shown a common form of a permanent magnet. It consists of a bar of steel bent into



1. Poles of Magnet. 2. Horse Shoe Magnet. 3. Magnetic Field.
4. Opposing Magnetic Field.
Fig. 216.

the shape of a horse shoe, and then hardened and magnetized. A piece of soft iron, called an **armature,** is placed across the two ends of the horse shoe which assists in preventing the steel from losing its magnetism.

This is only one of the many forms into which a permanent magnet may be made.

In the Fig. 216 (1) is shown a **bar** magnet which has been dipped into iron fillings. It will be noticed that the fillings cling to it in great numbers at the **two ends** of the bar, but there are but few attracted to the **middle** of the bar. The ends of the magnet where the attraction is the greatest, are called the **poles,** and the part of the magnet where there is no apparent magnetic attraction, is called the **neutral** zone.

An imaginary line shown through the center of the magnet from one end to the other end, connecting the two poles, is called the **axis of magnetism.**

Compass.—The most common example of a magnet is the **compass** needle. Such a needle, or magnet, always places itself so as to point north and south, and the same pole always points to the north and the other to the south. The end which points north, is called the **North Pole,** and the other the **South Pole.**

If the north poles, or south poles, of two such compass needles be brought near each other, they will be repelled, but when the north pole of one needle is brought near the south pole of the other, they will **attract** each other. This demonstrates what has been hertofore stated, viz.: that **like** poles **repel,** and **unlike** poles **attract** each other. The **earth** is the magnet which makes the compass always point north and south, that is towards the **magnetic** poles of the earth, which poles nearly coincide with the geographical north and south pole of the earth.

A magnet always has two poles, however minut the particles into which it may be broken, and thes poles always possess the same magnetic properties.

Magnetic Field.—The space surrounding a magnet in which a magnetic substance will be attracted, or repelled by it, is called the **magnetic field.**

In Fig 216 (3) is shown the magnetic field surrounding a bar magnet, which can be seen by placing a sheet of paper upon such a magnet, and spreading iron filings evenly over the paper. By tapping the paper lightly the fillings will form themselves into a series of **curved lines** extending from one pole of the magnet to the other.

This can be repeatedly tried with different magnets and under different conditions, and it will be found that the filings will always form themselves into these well defined curves extending from one pole to the other.

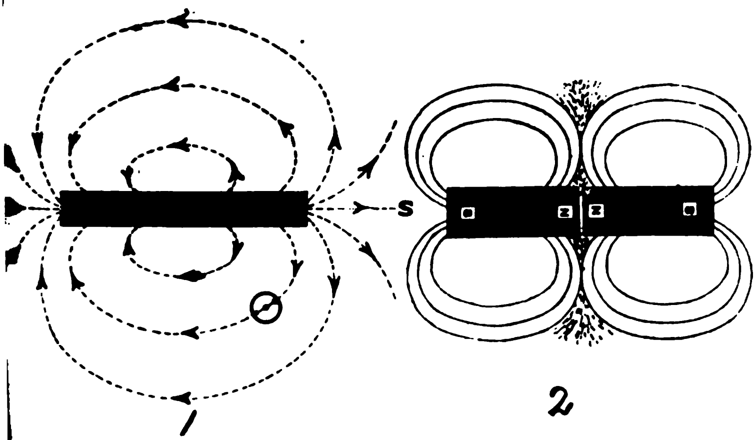
These lines are called **lines of force,** or lines of **magnetic** force.

Lines of Force.—The formation of these definite and well defined lines indicates that the magnetic field exerts its influence always in certain fixed directions.

Should two **like** poles, as shown in Fig. 216, (4) be brought near each other, then their repellant forces can be clearly seen from the direction of the lines of force which tend to move away from each other. This is also shown in Fig. 217 (2).

All lines of force are assumed to pass out from the **north pole,** make a complete circuit through the surrounding medium, re-entering the magnet through the **south pole,** and thence pass through the magnet to the north pole again.

These lines of force during their entire circuit are shown in Fig. 217 (1), and also the circuit of the line



1. Directions of Lines of Force. 2. Opposing Lines of Force.

Fig. 217.

of force when the **like** poles of two magnets are brought near each other, as seen in Fig. 217 (2).

These lines of force can be traced by a small compass the same as by using iron filings. Should a compass be moved through the magnetic field, the north pole of the needle will always point in the direction of the lines of force, and the center or pivot of the needle will describe a path, or circuit, coinciding with the lines of force.

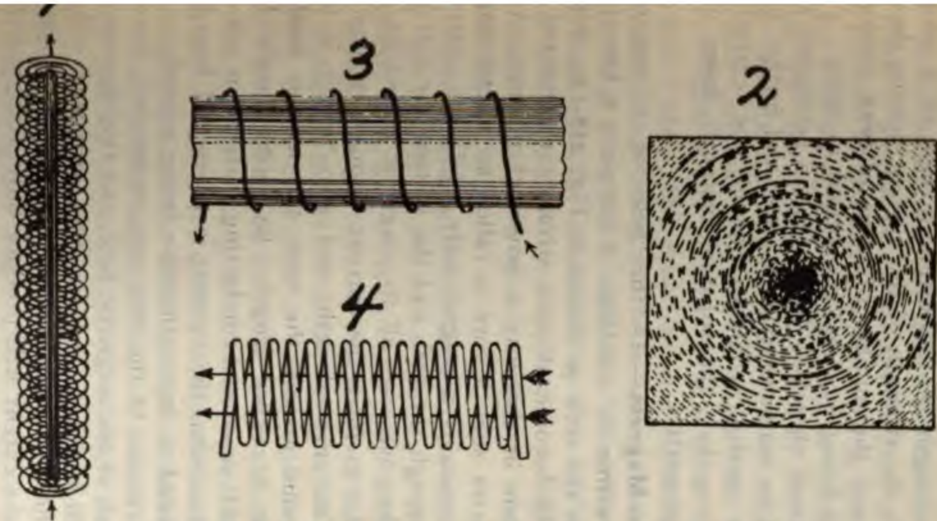
Magnetic Induction.—Every substance as soon as it becomes magnetized, as well as every conductor of electricity, is surrounded by this magnetic field, and this action of developing magnetism in **other bodies** than itself is called **magnetic induction.**

In Fig. 218 (1) is shown the magnetic **whirl** which completely surrounds every conductor conveying a current of electricity.

In Fig. 218 (2) is shown these lines of force forming a magnetic field around the end of a bar magnet.

Solenoid.—If a wire be made into a **coil,** and a current of electricity, be passed through this coil as shown in Fig. 218 (4), the coil partakes of all the properties of a permanent magnet. Such a coil is then called a **solenoid.** The magnetic field surrounding each turn of the wire, unites to form one **magnetic field,** which surrounds the entire coil similar to the field that surrounds a single bar magnet, as illustrated in Fig. 217.

The solenoid will retain its magnetic properties only as long as the electric current passes through it. The direction of the lines of force as shown in the above illustration are the same as those of a permanent magnet, issuing from one end and entering into the other end of the coil. If the coil be suspended so as to be free to turn, it assumes a position such that its axis will



1. Magnetic Whirl. 2. Magnetic Field Around a Conductor. 3. An Electro-Magnet. 4. Solenoid Showing Direction of Lines of Force.
Fig. 218.

point north and south, and so act like a compass needle.

The strength of the magnetic field of a solenoid **varies** with the **strength** of the current flowing through the coils, and the number of **turns of wire** composing the coils, it being in direct proportion to same.

A solenoid therefore differs from a permanent magnet in that its magnetic powers vary, and further in being under perfect control. Should the current be **stopped** altogether, the solenoid instantly **loses** all its magnetic properties.

Electro-Magnets.—As the field of a magnet is strongest **within** its windings, if we place a bar of soft iron within the coils as shown in Fig. 218 (3), this bar or core will become at once strongly magnetized, and can be made in this way a powerful magnet. A coil provided with such a core is called an **electro-magnet.** This core remains a magnet only while the current is flowing through the coil, and the instant the current is shut off, the core loses all its magnetic properties.

In order to force the current through each turn of the wire its entire length, and also permit it to be closely wound around the core, the wire is **insulated** throughout its entire length. By being insulated, or covered with some non-conducting material as silk, cotton or guttapercha, the current is prevented from being short **circuited** or from otherwise being wasted.

The presence of the iron core enormously increases the strength of the magnetic field, and this increase continues until the iron core becomes **saturated** with the magnetic lines of force, at which point any further increase in the curent will produce only a slight increase in the strength of the field.

Magnetic Induction.—We have seen that all magnets are surrounded by a magnetic field, and also that

electric charges will induce a current of electricity in other bodies brought in contact with them.

When a substance is brought within a magnetic field, a current of electricity is produced in it the same as if it had been brought in contact with an electric charge. Electric currents produced in this way are called **induced currents,** and by this process of induction one body may become electrified or magnetized by simply being brought in the presence of a magnet, or another electrified body; the same as a substance becomes heated by being brought near a heated body, without ever coming in contact with it. The magnetic field which surrounds the magnet, or a wire carrying a current of electricity, can be compared to a highly heated stove which imparts its heat or energy to everything in the area heated by it.

Induced Currents.—The **induced currents** of electricity are usually produced by moving a body **across** a magnetic field, and thereby cutting the lines of force. This produces a current in the conductor or moving body, though it makes no difference whether the magnet itself or the conductor is moved, just so the lines of force which emanate from the body are cut.

This can be clearly seen if a magnet be quickly thrust into a coil of wire, as a momentary current will be produced around the wire, and this current will continue so long as the magnet is kept in motion.

The quicker the magnet is moved back and forth in the coil, the greater will be the strength of the current induced in the coil.

Withdrawing the magnet from the coil, produces a flow of current in an **opposite** direction to that produced by thrusting it in the coil.

If we join the two ends of a wire so as to make a

complete circuit, and move this wire rapidly in front of a magnet, a current will be induced in the wire.

This action of the magnet in producing an induced current in the wire, is **called electro-magnetic induction.**

Upon this property of electricity, which was discovered by Faraday in the year 1831, all dynamo-electric machinery is based, as well as all induction coils and alternate current transformers.

When a wire carrying a current of electricity is brought **near** another wire carrying no current, there is excited in the latter wire a sympathetic current, but which moves in an **opposite** direction to that of the current in the first wire. While this current, which is called as we have seen an induced current, is much weaker than the current in the first wire, in all other respects it is **exactly** similar, and produces the same **effects.**

Such induced currents are produced **only** by an **alternating** current, as will be hereafter shown. As its uses are universal, in fact, are the foundation upon which almost all applied electricity rests, its principles must be thoroughly understood.

Conductors and Non-Conductors.—Conductors are substances which readily allow an electric current to pass from one part of them to another.

Non-conductors, or insulators as they are most frequently called, are those substances which do not permit a free passage of electricity, as they offer a certain resistance to its passage.

For instance, one end of a glass rod can be electrified, and yet the other end remain wholly **unaffected**, as glass is a **poor conductor.** On the contrary, when any metallic substance is charged with electricity, however small may be the charge, the electricity is at once uni-

formly distributed over its **entire** surface. This is because metals offer but little resistance to the passage of electricity, and hence are **good conductors.**

As all bodies offer a certain amount of resistance to the passage of an electric current, and none entirely resist it, there are no **perfect** conductors, and likewise no **perfect** non-conductors.

The following list of substances is arranged in order of increasing resistance, viz.:

Conductors.	Partial Conductors.	Non-Conductors or Insulators.
Silver.	Cotton.	Oils.
Copper.	Dry wood.	Porcelain.
Other metals.	Marble.	Wool
Charcoal.	Paper.	Silk.
Water.		Resin.
The body.		Guttapercha.
		Shellac.
		Ebonite.
		Paraffin.
		Glass.
		Air.

From this it can be seen that silver is the best conductor, and air the poorest. Air is therefore the best non-conductor or insulator.

Copper is chiefly used in all electrical work, as it is not only one of the best conductors, but also one of the most ductile and strongest, and at the same time the cheapest.

Transmission.—Electricity is transmitted over the **surface** of a body, and not **through** the interior, as is heat and light. The interior of a conducting body can be made hollow, or even filled with a non-conducting material, and it will have no effect upon its conductivity.

Electrical Measurements.—The four principal units used in the measurement of a current of electricity are:

The **Ampere,** or the unit denoting the rate of flow of the current, or its **strength.**

The **Volt,** or the unit of electrical potential, or **pressure.**

The **Ohm,** or the unit of resistance.

The **Watt,** or the unit of power, and is obtained by multiplying the current by the voltage, or by multiplying the square of the current by the resistance.

For large units the term **kilowatt** is used, which is equal to 1,000 watts, the abbreviation being K. W. The kilowatt hour is the energy expended in one hour when the power is one kilowatt.

Analogy.—The relation of the first three units can be better understood by the analogy often used of the flow of water through a pipe. The force which causes the water to flow through the pipe is called the head, or **pressure**; that which **resists** the flow is the friction of the water against the pipe, while the **rate of flow,** or current, may be expressed in gallons per minute. Now, as the pressure, or head increases the rate of flow, or current, increases in proportion, but as the resistance increases the current diminishes.

In the case of **electricity,** the electromotive force, or potential, corresponds to the head of water, or **pressure**; and the **resistance** of the conductor, to the friction of the water against the pipe; while the **strength** of the current is the ratio of the electromotive force to the resistance of the conductor. This ratio was discovered by Dr. Ohm, and is therefore called Ohm's law, and is the foundation of applied electricity, for there is hardly a problem in electrical work in which it does not enter.

Ohm's Law.—This law is usually expressed algebraically, thus:

$$\text{Strength of current} = \frac{\text{Electromotive force.}}{\text{Resistance.}}$$

$$\text{or Amperes} = \frac{\text{Volts}}{\text{Ohms.}}$$

$$\text{or } C = \frac{E}{R} \text{ as it is commonly expressed,}$$

in which C equals current, E equals the electromotive force expressed in volts, and R equals resistance, expressed in Ohms.

From this formula is derived $E = C \times R$, or $R = \frac{E}{C}$, these terms all being dependent upon each other. For watts we have the formula $W = E \times C$.

With any two of these terms given, it can be seen that the third term can readily be found. As seen, the current varies **directly** as the voltage varies, and **indirectly** as the resistance varies. That is, the current increases when the voltage increases, and decreases when the resistance increases. With the above four formulae any calculation in electricity becomes most simple. For instance, suppose you wish to find what current will flow through a resistance of 3 Ohms, at a pressure of 6 volts.

Substituting in formula (1), we have C (amperes) equals $\frac{6}{3} = 2$ amperes.

Again, we have a lamp the resistance of which we

know to be 12 Ohms, and we are using 2 amperes of current; what E. M. F. (volts) is necessary?

Using formula (2), we have E (volts) equal 2 x 12 = 24 volts.

Suppose we wish to know the resistance of a wire coil through which a current of 6 amperes will pass with 20 volts pressure?

Substituting in formula (3), we have R (Ohms) equal $\frac{20}{6} = 3\ 1\text{-}3$ Ohms. Lastly, we have a small motor taking 2 amperes at 5 volt pressure to run it, how many watts of current does it consume?

Substituting in formula (4), we have W (watts) equals 2 x 5 = 10 watts.

Method of Measurements.—To ascertain the amount of current flowing in a circuit an ammeter, which is designated in Fig. 219 as A, is inserted in **series** in one of the mains. The whole of the current passing to the lamps L, therefore must pass through it and be measured.

A voltmeter, designated as V, is connected across the two main leads, or in **shunt** with the dynamo, and therefore measures the **difference** of potential between the two mains in volts.

Wattmeter.—This is an instrument for measuring the power consumed in a circuit supplied with a direct current, though wattmeters are now made for either direct or alternating currents.

As electrical **power** is equal to the product of the E. M. F. in volts and the current in amperes, these two factors must be taken into consideration in the construction of such an instrument.

This instrument is used to measure the electricity sold to customers, the record being kept in watt hours,

which is 1 volt x by 1 ampere x by 1 hour = 1 watt hour.

Construction of Meters.—Volt-meters are used to measure the potential **difference** between any **two** points in a circuit, and are therefore connected **across the** circuit.

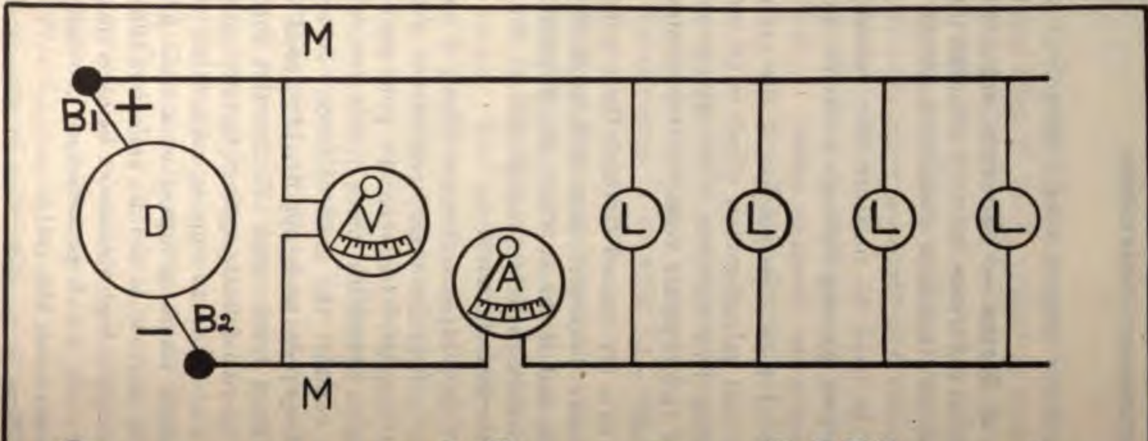
An **ammeter** is used to measure the **volume** or **amount** of the current passing through a circuit, and is therefore connected in the circuit in series.

The principle of their construction is the same as that of the differential galvanometer, which is an instrument for **comparing** two currents. The galvanometer consists chiefly of two separate coils, or two similar independent windings.

If equal currents are passed through these coils, or windings, in opposite directions there will be no deflection of the needle, but if the currents are **unequal**, the deflection of the needle will be proportional to the **difference** between the two currents.

Voltmeter.—The Weston voltmeter, which is one of the most accurate voltmeters made, consists of a horizontal permanent magnet. Between the pole pieces of this magnet is fixed a cylindrical piece of solt iron, which serves merely to conduct the lines of force. A coil is placed between these poles and supported by jewel bearings inserted in fixed brass cups. A directive force is given to this coil by two delicate springs fastened at each end of the coil, and made to oppose each other. The coil carries a pointer which swings over a scale graduated in volts. The current is led to and from the coil through these springs, a high resistance being connected in series with the coils, which permits only a small part of the current to act upon the coil.

Ammeter.—There is no difference in the construc-



Connection of Ammeter & Voltmeter.

Fig. 219.

ion of an ammeter and a voltmeter, except in the re-
istance of the instrument. In the voltmeter, there
hould be a very high resistance so as to take only a
ery small current for its operation. In the ammeter,
hich is connected in series in the main circuit, the re-
stance should be as low as possible so that the energy
onsumed will be slight.

Wattmeter.—This instrument consists essentially of
wo coils of insulated wire, one fine and the other coarse,
o connected in the electric circuit that they act upon
ach other.

CHAPTER XXV.

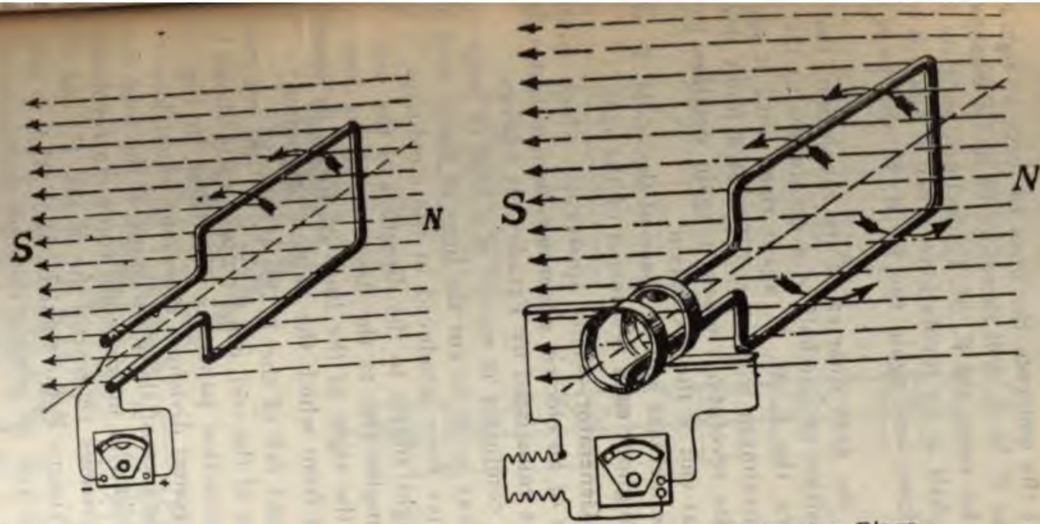
DYNAMOS AND MOTORS.

Theory of the Dynamo.—If a rectangular coil of copper wire is placed in the center of a magnetic field, with its plane lying perpendicular to the lines of force, as shown in Fig. 220 (1), the coil will in this position enclose the greatest possible number of lines of force. So long as the coil remains at rest in the magnetic field, no E. M. F. will be generated; but should the coil be rotated on its magnetic axis, as shown by the broken line, and in the direction indicated by the arrows, then the coil cuts the lines of force at right angles, and a current is at once generated. The E. M. F. generated in the upper side will cause the current to flow from left to right, and in the lower side of the coil from right to left, thus making a complete circuit of the coil.

Should a voltmeter be connected to the two ends of the coil, as shown in this diagram, the E. M. F. generated in the coil will be indicated by the deflection of the index needle.

As the current flows towards the lower terminal of the coil where it is connected to the voltmeter, and from thence out on the external circuit, this terminal becomes the positive pole or terminal, while the upper end of the coil becomes the negative pole or terminal, as through this coil the current returns to the coil after completing the entire circuit.

If the speed of rotation is kept constant throughout each revolution, the voltmeter will show the E. M. F. becomes greater as the coil revolves from its vertical position, and it continues to increase until the coil reaches the plane parallel to the lines of force, which will be when it reaches one quarter of its revolution, at



1. Coil Cutting Lines of Force. 2. Coil with Collecting Rings and Brushes Attached.

Fig. 220.

which point the coil cuts the lines of force at **right angles,** and the E. M. F. will therefore be at its **maximum.**

From this point the E. M. F. declines until the coil reaches one-half of its revolutions, when it again is in a vertical position, and again the E. M. F. will be at its minimum.

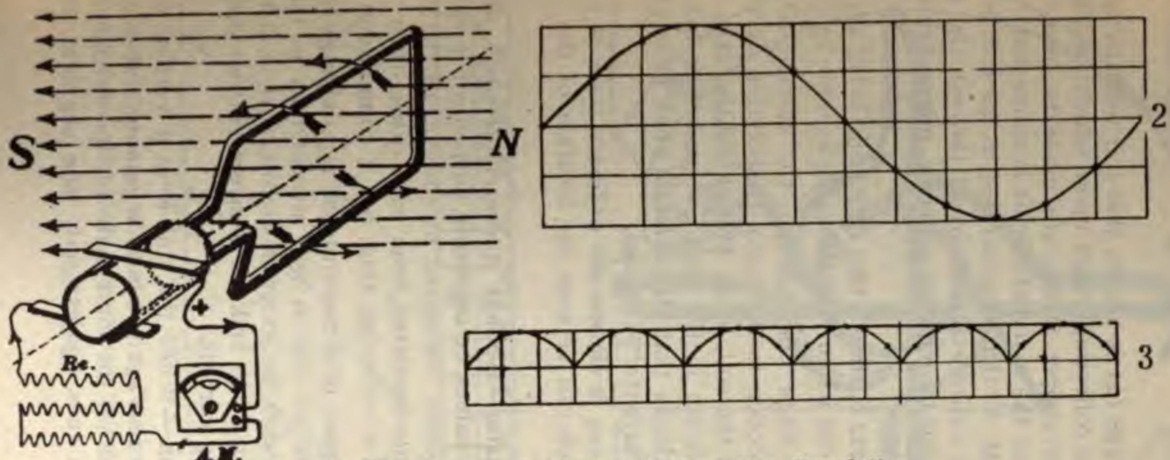
During the next quarter of its revolution, that is from the position of one-half of a revolution to that of three-quarters, the E. M. F. again **rises** until it again reaches its maximum when the coil is at a point three-quarters in its revolution, when it again **declines** until it is at zero at end of the revolution.

Thus, the increase and decrease of the E. M. F. will continue throughout **each** revolution of the coil.

Electric Generator.—This apparatus, which is the simplest form of an electric generator, demonstrates the principles first enunciated by Faraday, as follows:

"When a conductor is moved in a field of magnetic force in any way so as to **cut** the lines of force, there is an electromotive force produced in the conductor, in a direction at right angles to the direction of the motion, and at right angles also to the direction of the lines of force, and to the right of the lines of force, as viewed from the point from which the motion originates."

The rise and fall of the E. M. F. during one complete revolution of the coil, can be graphically shown by means of cross-section paper, as illustrated in Fig. 221 (2). The **horizontal** divisions represent equal intervals of time, and the sum of these divisions is the total time required by the coil in making one complete revolution. The **vertical** divisions represent the E. M. F., and the **sum** of these divisions is the total E. M. F. that is being generated in the coil in passing through each complete revolution.



1. Coil with Commutator. 2. Current During One Revolution of the Coil. 3. Current Rectified by Commutator.

Fig. 221.

In Fig. 220 (2) is shown this coil with its two ends connected to collecting rings upon which two brushes, made of two copper strips, are made to bear, and to which brushes the external circuit is connected. In this way the E. M. F. that is generated in the coil **flows** out and over the entire external circuit through the **positive** brush, returning through the upper or **minus** brush to the coil.

In Fig. 222 is shown **two** such coils being used, each coil sending out its current the same as done by one coil.

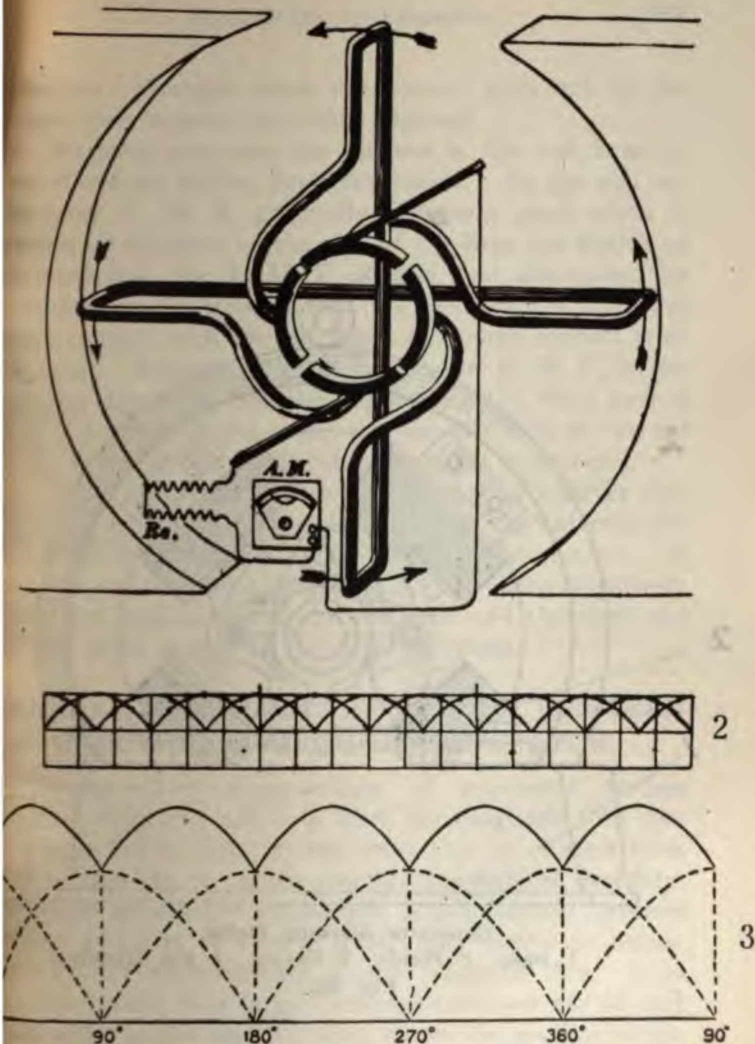
As seen from this diagram, the current **alternates** from one direction to the opposite direction during each revolution of the coil, being first above the axis, or middle line as shown in the diagram, and then below this line, which shows that **all** currents when generated, are **alternating** currents.

In Fig. 224 is shown the ordinary type of a generator, on which can be seen the location of the commutator.

Commutator.—Should these collecting rings be made in **two halves** or **segments**, instead of a solid ring, and **each** segment connected to one end of the coil and these segments **insulated** from each other, then it is no longer called a collecting ring, but a **commutator.**

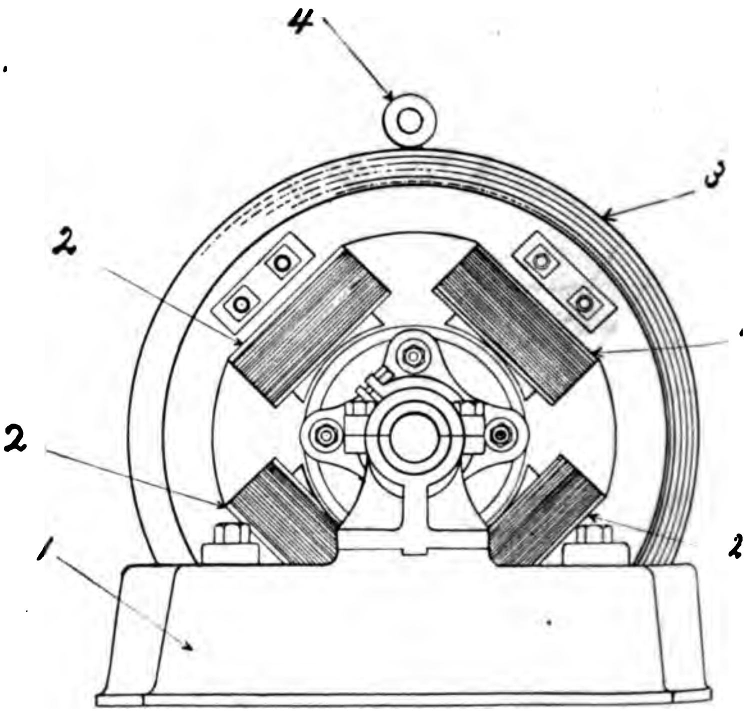
The purpose of a commutator is to **change** the flow of the current, so that it will always flow in the **same** direction through the external circuit, that is, it **rectifies** the current so as to make it a **direct** current instead of an **alternating** current.

Operation.—When the coil is in a vertical position both brushes rest against both segments, but as soon as the coil starts on the first half of its revolution, the minus brush rubs against only **one** segment, and the



1. Two Coils Showing Commutator. 2. Diagram of Direct Current from Two Coils. 3. Actual Curve Produced.

Fig. 222.



Generator Showing Fields.
1. Base. 2. Fields. 3. Casing. 4. For Handling.
Fig. 223.

lus brush through which the current goes out on the circuit, rests against the other segment.

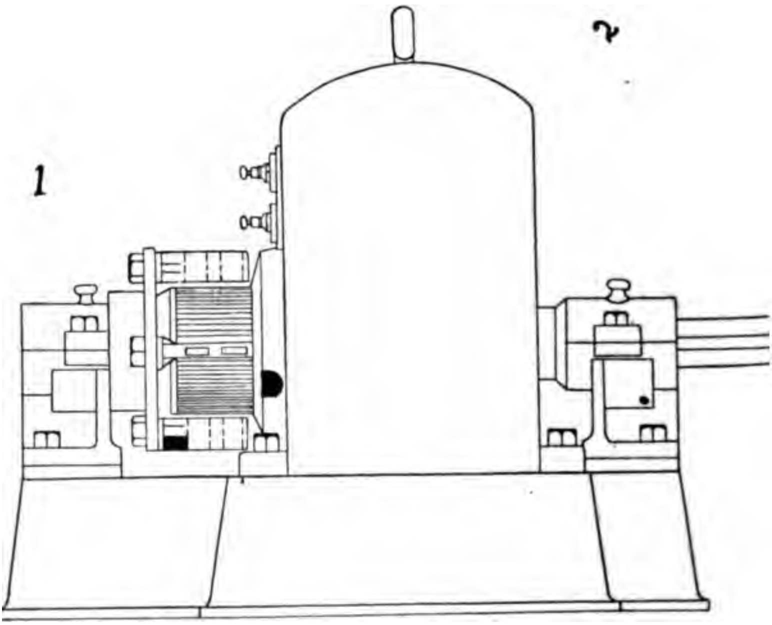
We have seen how the current in the coil flows in wo directions during each revolution. As the coil ro-ates, the E. M. F. gradually decreases until when it eaches 90 degrees, or the end of the first one-fourth of ts revolution, the E. M. F. is **zero.** At this point the egments are located so that the brushes are about to reak contact with one segment and make contact with e other. Further rotation induces an E. M. F. in the pposite direction, but the segments have then passed om one brush to the other, and the direction of current the external circuit therefore remains unchanged.

In Fig. 221 (3), is shown a diagram of a **direct** cur-nt, that is, the current as it flows over the external cir-it when it is rectified by the use of a commutator. It ill be seen from this diagram that the curve is entirely ove the middle line of the diagram, and therefore the irrent flows always in the **same** direction.

ENERAL CONSTRUCTION OF A WESTERN ELECTRIC COMPOUND GENERATOR.

Frame.—The cross-section of generator frames ust be sufficient not only from the **magnetic flux** that is intended to care for, but must also be of such form nd section as to insure perfect **mechanical stability.** n larger generators mechanical considerations demand form and size of section other than would be neces-ary by the requirements of the magnetic flux. It is or this reason that larger generator frames are of cast ron, while in the smaller ones, where the section neces-sitated by the requirements of the magnetic flux is greater than would be necessitated by mechanical strength, a special material of high magnetic perme-

[redacted]



4

Generator Showing Commutator.

1. Commutator. 2. Casing. 3. Shaft and Bearings. 4. Base

Fig. 224.

ility is used. By reason of this construction the best sults are obtained with a minimum weight of material.

In their standard construction the frame is divided **rtically**, which permits drawing the yoke apart hori-ntally, allowing the armature to be inspected or re-oved. It is also a great advantage in isolated plants limited distance between floor and ceiling as the ame can be easily handled without access to cranes or her lifting devices. In Fig. 235 is shown a generator ith the frame withdrawn, showing fields and armature.

The method of bolting the frame to the extended gine sub-base allows adjustment both horizontally d vertically, insuring a **uniform air gap** and a **perfectly lanced magnetic field**, conditions necessary to obtain e best operation of a generator. On account of lim-ed width of engine room it is sometimes impossible make use of the vertically divided frame construc-on; a **horizontally** divided yoke is then used.

Pole Pieces.—In generators having **solid** pole pieces ere is a considerable loss due to the **eddy currents** in e pole tips. This results in materially **reducing** the ficiency of the outfit with the consequent **increase** in e temperature of the pole tips. To eliminate as much possible these wasteful currents, the laminated pole ece construction is adopted, the pole pieces being built p of thin sheets of thoroughly annealed mild steel, the arious sheets being both bolted and riveted together. ig. 226 shows one of the separate pole-piece sheets and so a pole piece assembled ready to be placed in the amping plate which is used in the process of molding. he metal of the frame is poured around the outer and gged ends of the pole pieces. By this construction an rea of magnetic contact between the pole pieces and he frame is obtained which is nearly three times greater

Pole Pieces.

Field Coils.

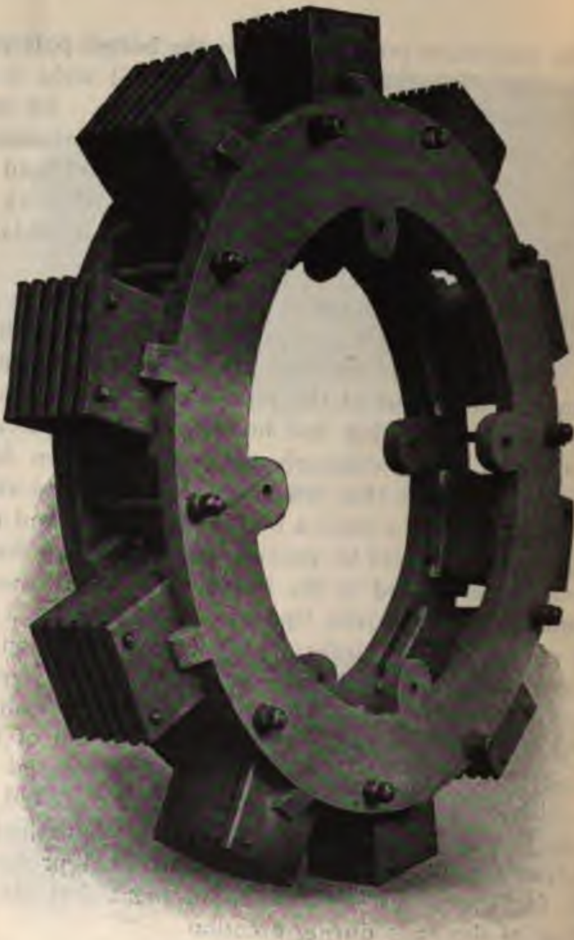
Fig. 226.

an the maximum possible area of the **bolted pole-piece** nstruction. In addition to this a partial weld is obned between the pole pieces and the yoke. By these ans a frame is obtained, the **magnetic resistance** of ich is reduced to the lowest possible point and the oility to an unequal magnetic distribution, with the ending sparking, is much less than would be obtained other forms of construction.

While the usual methods employed in building gentors having the pole pieces cast **integrally** with the me, permit, in the finished product of **variations** in chanical placement of the pole pieces, the method iltrated for assembling and holding the pole pieces in ce during the process of molding, has been found entirely eliminate this difficulty, and, as stated above, assure at the same time a better mechanical and magic joint than would be possible in a generator having pole pieces **bolted** to the frame. In order to assure **similarity** of the pole tips of all pole pieces, a conion necessary for uniform magnetic distribution and rkless operation, each tip is machined to a standard uge after the pole pieces are cast into the frame.

Field Coils.—In the standard construction of these ls, as shown in Fig. 226, the shunt and series field ls, although separately wound and insulated, are unted on a single metallic spool. This method has advantage of the additional mechanical protection, ich facilitates not only the shipment but also the ndling of the coils during erection

Armature Cores.—The armature is of the iron-clad pe, as shown in Fig. 228. In order that it may have minimum loss the armature core is made of thin discs doubly annealed sheet steel. After the slots have en carefully punched in the periphery of these discs,



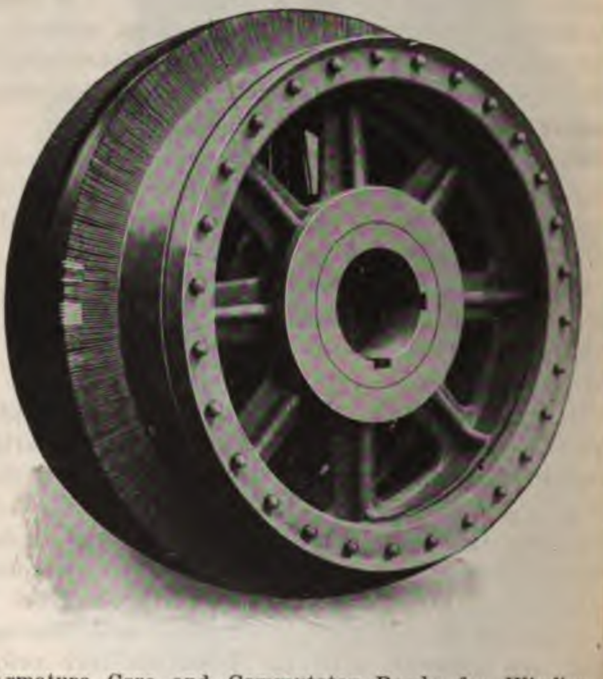
Pole Pieces in Frame.

Fig. 227.

the final annealing is given. By this method any hardening effect caused by the punching of the slots, is removed. Radial ventilating spaces are provided, which connect with horizontal openings in the armature center, allowing a thorough system of ventilation. The smaller armatures are built up of **continuous rings,** while in the larger ones, on account of the difficulty of obtaining iron in sheets sufficiently large, the method of building in **segments** has been adopted.

Winding Armature.—In winding the armature, as shown in Fig. 229, **solid bars** of specially drawn copper are used. The coils are enlarged in cross-section at the ends of the armature, Fig. 230, thus obtaining a very low armature resistance and a consequent gain in efficiency, while all the advantages of a solid bar winding are secured. This results in higher efficiency and lower temperature.

The bars are formed into coils before being placed on the armature so that when complete a perfectly symmetrical and balanced winding is secured, as shown in Fig. 231. They are insulated individually and in groups, the insulation, as well as the bar itself, being continuous from segment to segment of the commutator. At the various steps in the insulation process the bars are immersed in insulating compound and thoroughly baked. An illustration of the armature core prior to placing the coils thereon is shown in Fig. 228. The shape of the slot and the notches near the top of the slot permit of retaining the coils in place by means of fibre wedges. In addition to these wedges, on the smaller sizes the coils are held in place at the pulley or engine end of the armature by a brass ring extending over and clamping the ends of the coils, giving the armature the appearance as shown in Fig. 232. In the



Armature Core and Commutator Ready for Winding.

Fig. 228.

sizes this construction is not used but a finishing s placed at the pulley or engine end of the arm- and band wires are used on that portion of the ire winding lying outside of the armature core.

ie armature, after being built up in this way and having the commutator and armature winding in position, may then be mounted on the engine

mmutators.—the commutators are of a very **onstruction,** enabling them to withstand strains expansion and contraction and centrifugal force. gments are made of the very best drawn copper, ive riveted to them rolled copper tangs. These its are **insulated** from each other by specially pre- nica of a sufficient degree of hardness to produce a n wearing surface. In all but the smaller sizes gments are mounted upon a cast-iron center from they are insulated by mica. The completed com- r is then mounted upon the extended hub of the ire center, thereby permitting it to be removed he armature without disturbing the armature ing. A thorough system of **ventilation** is provided ans of horizontal air ducts. In the smaller sizes, r that this ventilation may be obtained, it is neces- cast the commutator center integrally with the ire center. The segments are then mounted in the r described above. This construction does not of the removal of the commutators from the arma- enter, but as the total weight of the completed ires in the sizes in which this construction is used ll, in case of accident the complete armature may dled without any difficulty.

ush Holders.—Fig 233 illustrates the brush holder ing and shifting device. Each set of brush holders

Armature During Winding.

Fig. 229.

is mounted upon a brush holder arm supported from a circular ring. This ring is carried in supports projecting from the yoke, the entire device being moved around the commutator by means of a hand wheel at the side of the machine. It will be readily seen that this arrangement gives an extremely stable construction.

The brush holders are designed so that the brushes may be moved in a direction radial to the surface of the commutator. Each brush is held firmly in a clamp in such a manner that the current does not pass through any sliding contacts.

The current is conducted from the clamp through copper strips, thus eliminating any danger of affecting the tension springs. The brush holder clamp and brushes themselves are small and light, and, having very little inertia, follow the commutator quickly.

Any brush may be lifted from the commutator without disturbing the adjustment of the others, and all brushes may be adjusted independently. A single arm with brushes and with parts is shown. By means of the eccentric insulating bushing, as shown in Fig 234, each individual arm may be adjusted to obtain perfect uniformity of spacing of the brushes about the commutator.

Inspection and Tests.—During the process of manufacture, all parts are subjected to rigid inspection and tests and the completed machines are run for a sufficient length of time to make sure that they come within the guaranteed limits of heating, sparking, etc. The insulation of the various parts of the machine and the completed machine are tested by the application of a high voltage, in accordance with the standard specifications adopted by the American Institute of Electrical Engineers.

The Dynamo.—The dynamo is therefore a machine

Coils Enlarged for Armature Winding.

Fig. 230.

Symmetrical and Balanced Coils for Armature Winding.

Fig. 231.

driven by power, usually steam or water, and producing the necessary **pressure** for the production of an electric current.

A dynamo when in action is like a cistern at a high evel, or a pump, for it urges or forces the current hrough the conductor. Without such **force** or **pressure** as produced by the dynamo, there would be no more low of an electrical current, than there would be of water from one receptacle to another, when both are on he same level.

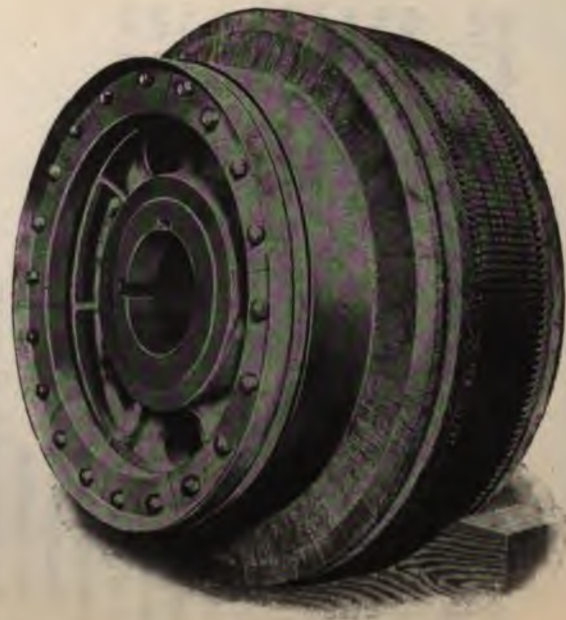
Classes.—Dynamos are classified into (1) Uni-polar, (2) Bi-polar, (3) Multi-polar machines, according to the number of pole pieces upon them. They are used for hree principal purposes:

1. Incandescent lighting.
2. Arc lighting.
3. For distribution of power.

When used for **power** purposes, the machine is alled a **generator**, that is, when it generates electricity be used through motors. Such an electrical machine its simplest form consists of two main parts: (1) an **rmature,** which in revolving induces electromotive rces in the conductor wound upon it; (2) a field maget, whose function is to provide a field of magnetic nes to be cut by the armature conductors or coils as ney revolve. In all dynamos, whether for direct or alernating currents, these two parts are the same. Usully the field magnet remains stationary while the armaure rotates, but in recent patterns of alternators, the rmature remains stationary, and the field magnets rotate.

It is always the **field magnet** which maintains its magnetism steady during the revolution, while the magnetism of the **armature** alone regularly changes, and this

Brush Rocker Ring.
Fig. 233.



Completed Armature.
Fig. 232.

variation of the magnetism determines the type of machine. It has been found most convenient to supply incandescent lighting systems by the constant **potential** system, and arc lighting systems by the constant **current** system, as will be hereafter explained.

In Fig. 223 is shown the **fields** on the ordinary type of generators.

The essential difference as we have seen between a direct current machine and an alternator, as an alternating current machine is called, is the use of a **commutator** upon the former machine for rectifying the current, that is, to change it from an alternating to a direct current. The commutator is attached to the **armature** and revolves with it.

In the case of an alternator there is no need of a commutator, but metallic rings, known as collecting rings, take its place, the collecting brushes pressing against them, as shown in the illustrations.

The dynamo, therefore, consists of **five** essential parts, viz.:

(1) The armature, or revolving part.

(2) The field magnets which produce the magnetic field in which the armature rotates.

(3) The pole pieces.

(4) The commutator or collector.

(5) The collecting brushes.

In Figs. 223 and 224 are shown the principal parts of a generator, or dynamo.

Types of Dynamos.—There are two principal types of dynamos: (1) Direct current, and the (2) Alternating current machine.

The direct current machines are divided into three classes: (1) Series wound; (2) Shunt wound; (3) Com-

Rheostat.

Brush Holder Arm with Eccentric Bushing Parts.

Fig. 234.

pound wound, depending upon the manner the field magnets are connected to the armature.

Series Dynamos.—The manner in which the connections are made on this type of machine can be seen from Fig. 238. In this type, the **whole** of the current generated in the armature, passes direct through the coils of the field magnet, which is wound with several turns of heavy wire, and thence out to the external circuit. The current in passing through the coils of the field magnet energizes same, creating a magnetic field between the N. & S. poles, in which magnetic field the armature revolves as shown clearly in the cut.

Shunt Wound Dynamos.—This type which is shown in Fig. 238, differs from the series wound machine in that the **whole** of the current does **not** pass through the field coils, but an independent circuit is used for exciting its field magnet. This independent circuit is composed of a large number of turns of fine wire, which are wound around the field magnet and connected direct to the brushes, so as to form a by-pass or shunt to the brushes and external circuit, in addition to the main current, which is taken off direct from the brushes. There are **two** paths presented to the current as it leaves the armature, viz.: The external circuit and the path through the field coils. Most of the current flows through the external path, as it offers much less resistance than the shunt path through the field coils, it being of much larger wire. The resistance of the shunt circuit is always made very great, as compared to the resistance of the armature and external circuit, as this circuit is used alone to secure a **closer regulation** of the machine than afforded by the series type. The strength of the current through the field coils rarely exceed 15 amperes, even in the largest size machines.

Compound Wound Dynamos.—This type, as shown in Fig. 238, is a combination of the series and shunt wound machines, the field magnet being wound with two sets of coils, one set being connected in series, and the other set in parallel with the armature and external circuit.

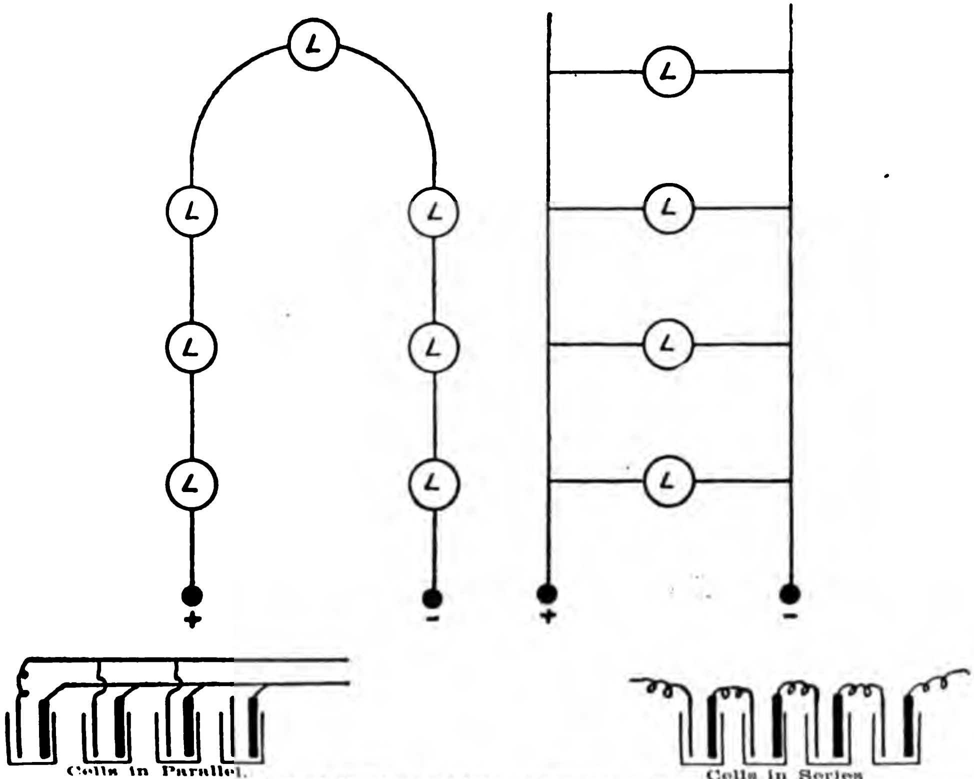
This affords a much closer regulation than the shunt type, and automatically maintains a constant pressure, and is therefore used almost exclusively for incandescent lighting.

Self-Exciting Machines.—The above three types are what is known as **self-exciting machines,** as they require no independent battery or dynamo for exciting their field magnets, but excite their fields themselves, as above described.

Separately Excited Machine.—In order to operate this type of machine, known as an **alternator,** an independent direct current dynamo or battery is necessary for exciting its field magnets, called an exciter, which is shown in Fig. 239. It is therefore not in general use for small installations, being principally used where an **alternating** current is required, as with an alternating current a self-exciting machine is impossible, owing to the fact that the fields cannot be magnetized with such a current, a direct curent being necessary for this purpose, as above explained.

The E. M. F. and current of this type of dynamo is regulated by varying the strength of the magnetizing current produced by the independent dynamo or battery which is connected direct to the field coils. The strength of this independent current is regulated by the regulator R.

Coupling of Dynamos.—In large installations, such as central generating stations, it is neither economical



Connection of Cells and Lights in Series and Parallel.

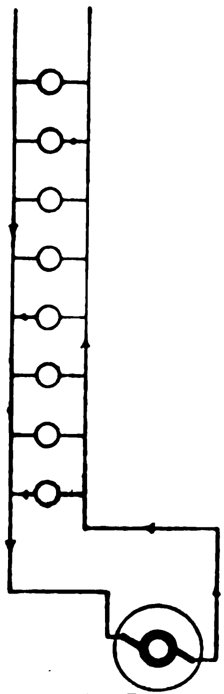
nor desirable that the **entire** current should be furnished from a single dynamo or generator. As it is economy to always work a dynamo at **full load,** or as near a full load as possible, it is manifest that this would be impossible with only one machine, owing to the fluctuation of the load. In order to secure a maximum efficiency it is usual to divide up the plant into a number of **units,** so that the load can be taken care of at all times, irrespective of its fluctuations. At the "peak" of the load, that is where the load is the heaviest, all the units can be worked, and as the load decreases the units can be cut out, so as to always keep a **full load** on the machines kept running.

The **output** of a dynamo is composed of two factors, the pressure, or voltage, and the current, or amperage. Either or both of these can be increased by the addition of **more machines,** the same as the boiler horse power of a plant can be increased by the installing of more boilers. The uses of electricity at the present time require the maintenance of either a constant current, or a constant pressure in a circuit, and to comply with these requirements it becomes necessary to connect the dynamos or generators together in several different ways.

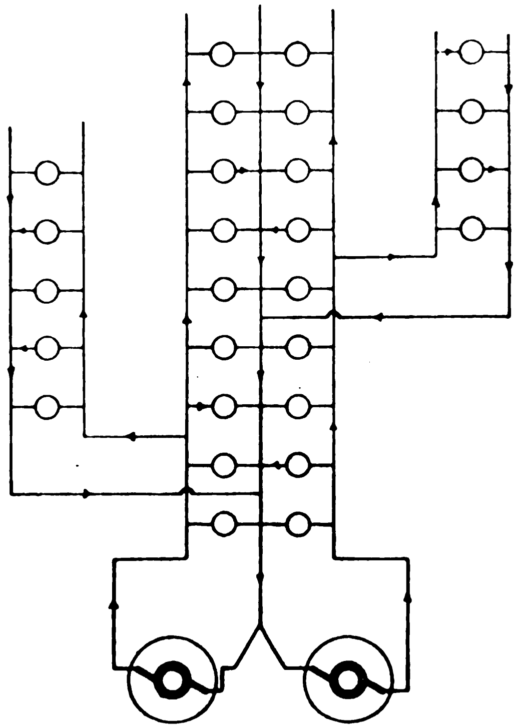
In coupling two or more machines in **parallel** the pressure or **voltage** of all the machines is kept constant, and the current or **amperage** alone varies.

In the **series** connection, the pressure or **voltage** of the machines is **increased,** while the current, or **amperage,** remains the same..

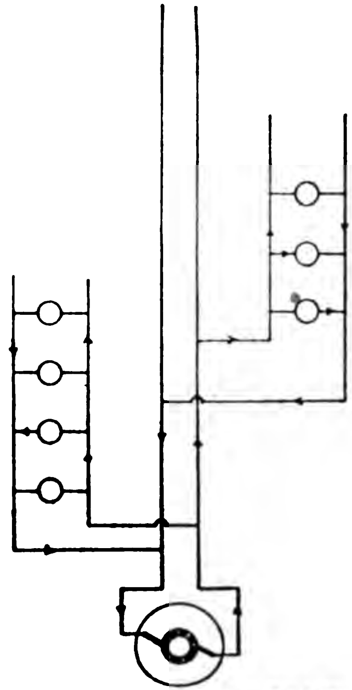
Fig. 236 shows the cells when connected in series and also when connected in parallel. Also, connection of lights in series and parallel.



Two Wire System.



Three Wire System.



Alternating System.

Systems of Connecting Lights.

Fig. 237 shows the principal systems of connecting incandescent lights.

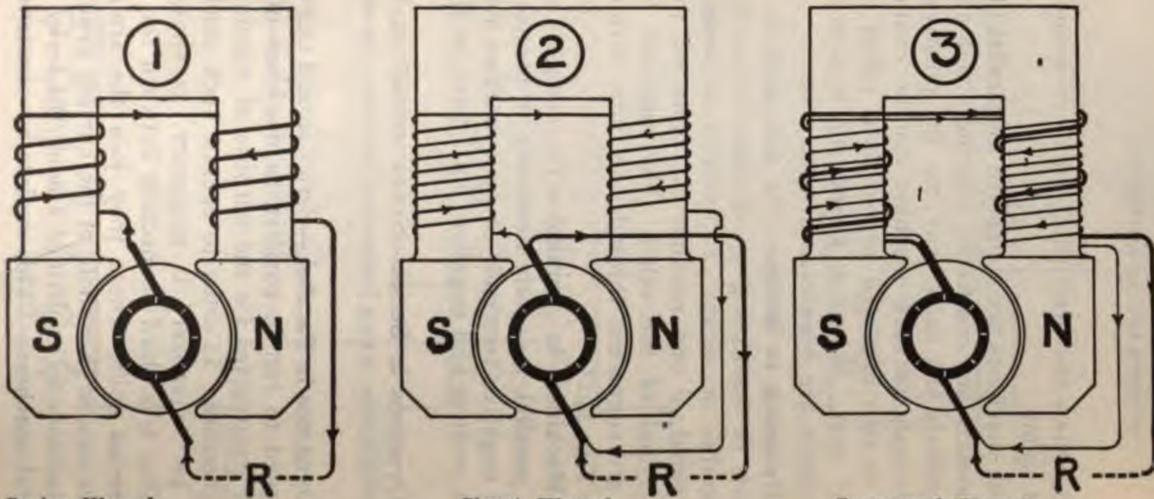
When the machines are connected in **parallel** all the positive terminals are connected together, and all the negative terminals the same way; or the positive and negative terminals of each machine can be connected respectively to two insulated copper bars, called omnibus or "bus" bars. When in **series,** the negative and positive terminals are connected to each other.

Shunt Dynamos in Series.—The following are the usual methods of connecting up dynamos so as to run either in parallel or series. To connect in **series** the positive terminal of one machine is connected to the negative terminal of the other. The ammeter, fuses and switch are connected through the outer terminals, as shown in Fig. 240.

Shunt Machines in Parallel.—To connect shunt machines in **parallel,** it is only necessary to connect the positive and negative terminals of each machine respectively to the positive and negative "bus" bars, as shown in Fig. 243.

Series Dynamos in Series.—Series wound machines will run satisfactorily when connected in series, as shown in Fig. 242.

Series Dynamos in Parallel.—Series wound machines are not adapted to run in parallel, as machines of this type are not constructed for the purpose of maintaining a **constant pressure.** In order to operate such machines in parallel, an "equalizer" is necessary, as shown in Fig. 241. This is a third connection between the ends of all the **series** coils, where they join the armature circuit. This causes the whole of the current generated by all the machines to be divided among the series coils of the several machines. This maintains constant the



Series Wound. Shunt Wound. Compound Wound.

Classes of Electric Generators.
Fig. 238.

fields of the several machines, and maintains an equality of pressure, thereby preventing reversal of polarity, and keeping the machines together under all conditions of oad.

Compound Dynamos in Series.—It is only necesary to connect the series coil of each together, as shown n Fig. 242. The shunt windings must be connected as single shunt.

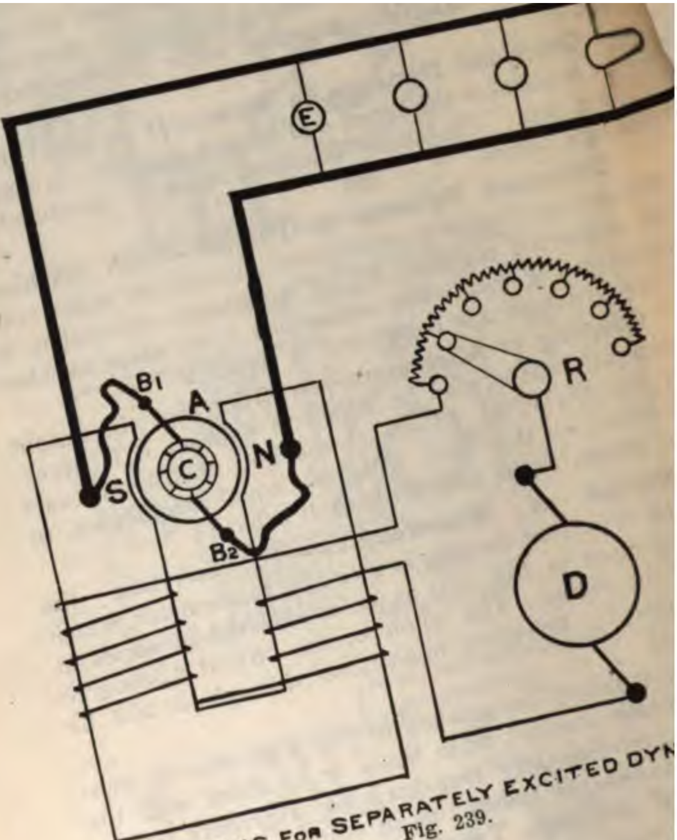
Compound Dynamos in Parallel.—Such machines vill not run together satisfactorily unless the series coils re connected together by an equalizing connection, as hown in Fig. 244. The connection is the same as when eries dynamos are connected in parallel.

Coupling of Alternators.—In order that the output f one alternator may be added to another it is necesary that the E. M. F. of each machine shall be in exact greement, so that they will have equal frequencies, or e in **phase**, or **in step** with each other.

Method of Measurements.—To ascertain the nount of current flowing in a circuit an ammeter, which designated in Fig. 219 as A, is inserted in **series** in e of the mains. The whole of the current passing to e lamps L, therefore must pass through it and be easured.

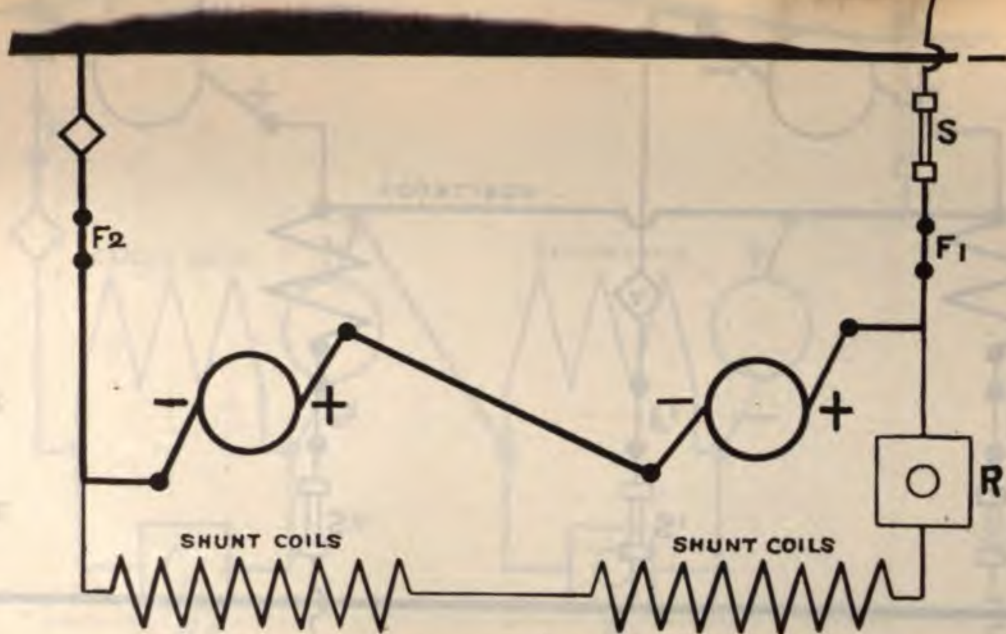
A voltmeter, designated as V, Fig. 219, is concted **across** the two main leads, or in **shunt** with the namo, and therefore measures the difference of potial between the two mains in volts.

Use of Different Types.—The series wound maines are used almost exclusively for street car mos, such a type being totally unfit for constant potenl work. The shunt and compound wound machines practically used for all power and incandescent lightg circuits. The constant current type is devoted



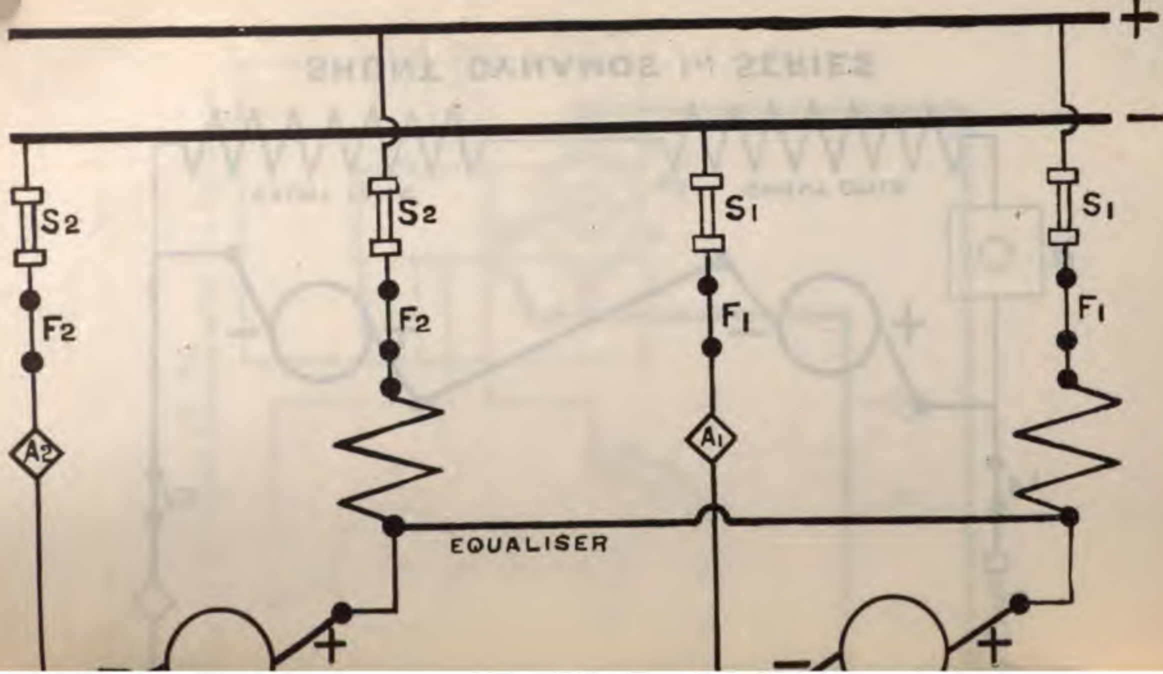
WINDING FOR SEPARATELY EXCITED DYN

Fig. 239.



SHUNT DYNAMOS IN SERIES

Fig. 240.


+
−
S1
F1
S2
F2
A1
A2
EQUALISER

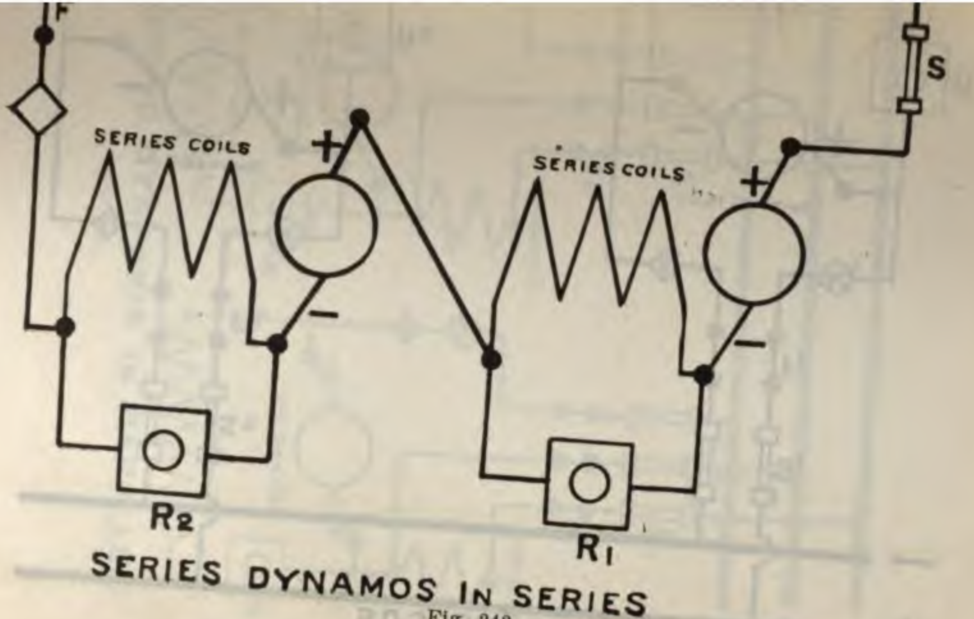
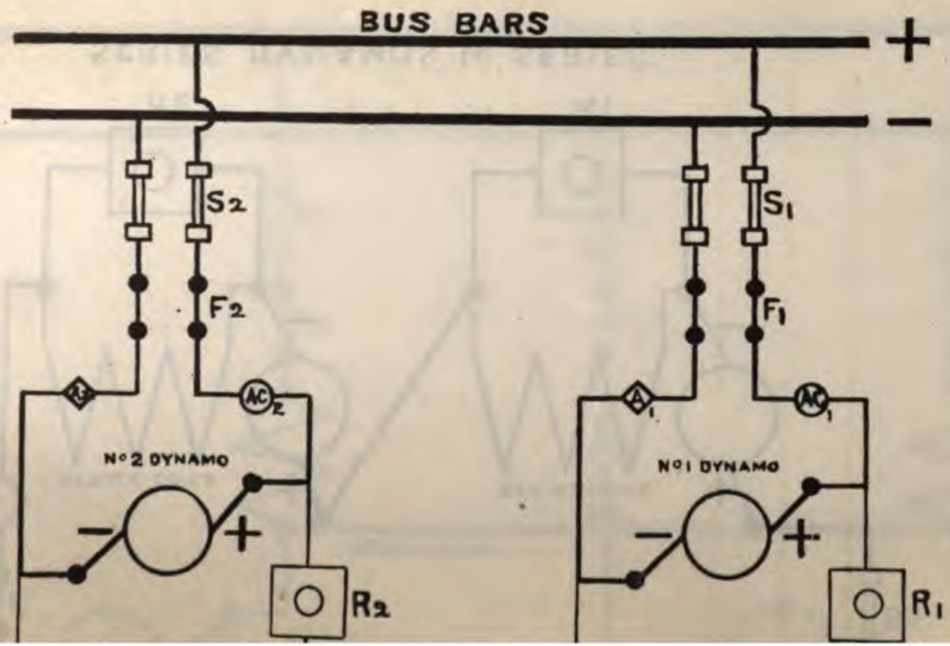
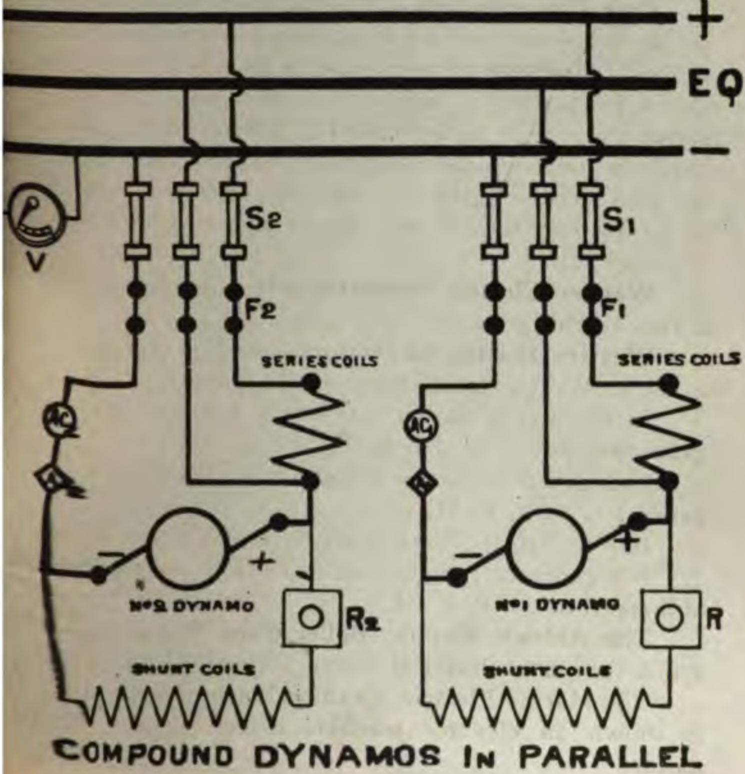


Fig. 242.


BUS BARS
+
−
S2
F2
AC2
N° 2 DYNAMO
R2
S1
F1
A1
AC1
N° 1 DYNAMO
R1



+
EQ
—
V
S2
F2
SERIES COILS
AC
No 2 DYNAMO
R2
SHUNT COILS
S1
F1
SERIES COILS
AC
No 1 DYNAMO
R
SHUNT COILS
COMPOUND DYNAMOS IN PARALLEL

Fig. 244.

mostly to arc lighting. Of the three types described above, the compound wound machine is by far the most used, owing to its close and automatic regulation.

Over-Compounding.—This is such a compounding of an electrical machine as produces under an increase of load an **increase** of voltage at its terminals. This is produced by placing a sufficient number of turns on the **series** coils so as to increase the difference of potential between the terminals of the machine above normal when the load increases. In this way the series coils are made to compensate for the drop in the armature and the external circuit.

Wagner Electric Generator.—In Fig. 246 is shown a view of this generator.

Western Electric Generators.—In Fig. 245 is shown a 125 K. W. generator, 125 volts and 125 R. P. M.

In Fig. 247 is shown a Western Electric 300 K. W. generator, 250 volts, 120 R. P. M.

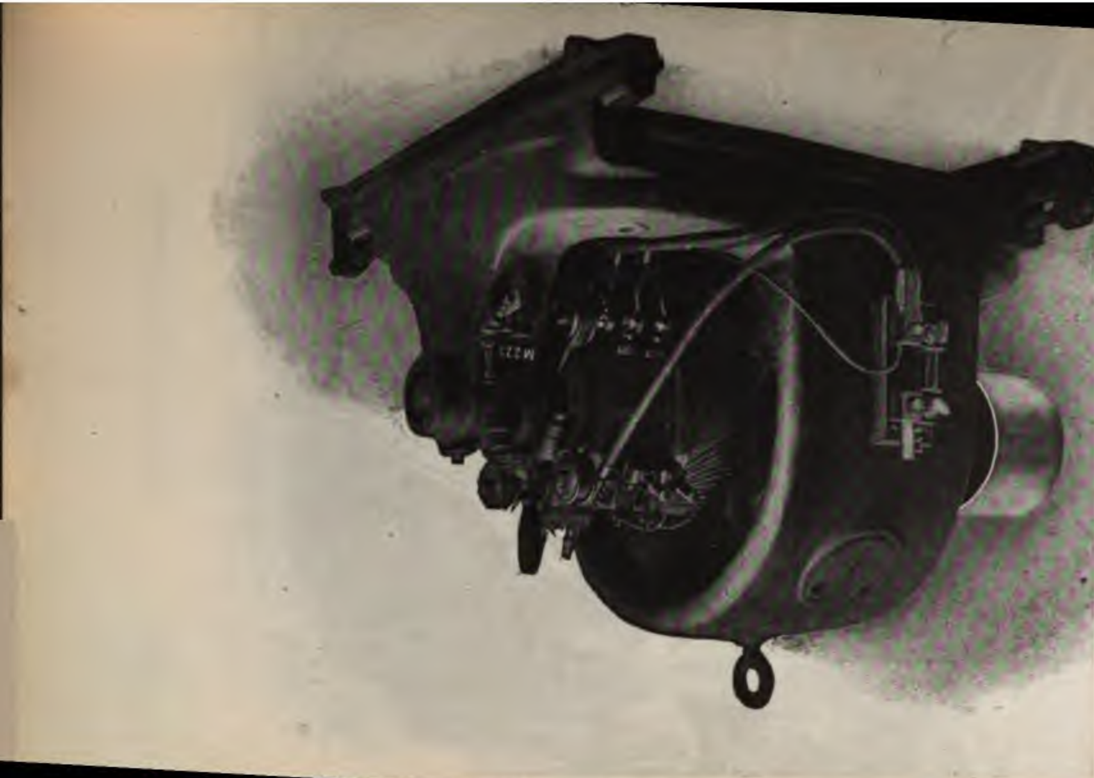
In Fig. 248 is shown a 800 K. W. Western Electric generator, 80 R. P. M.

In Fig. 249 is shown a 40 K. W. Western Electric, 125 volt generator, direct connected to a **gas engine**, run at a speed of 290 R. P. M.

The Aldrich Electric Boiler Feed Pump.—In Fig. 250 is shown an electrical driven boiler feed **pump.**

The Marine Electric Elevator Machine.—In Fig. 251 is shown an elevator machine driven by an electric **motor.**

Electric 125 K. W. Generator, 125 Volts, 125 R. P. M.
Fig. 245.



CHAPTER XXVI.

OPERATION OF DYNAMOS AND MOTORS.

Installation.—As there is practically no difference in the construction of dynamos and motors, the directions for their installation and operation applies equally to both.

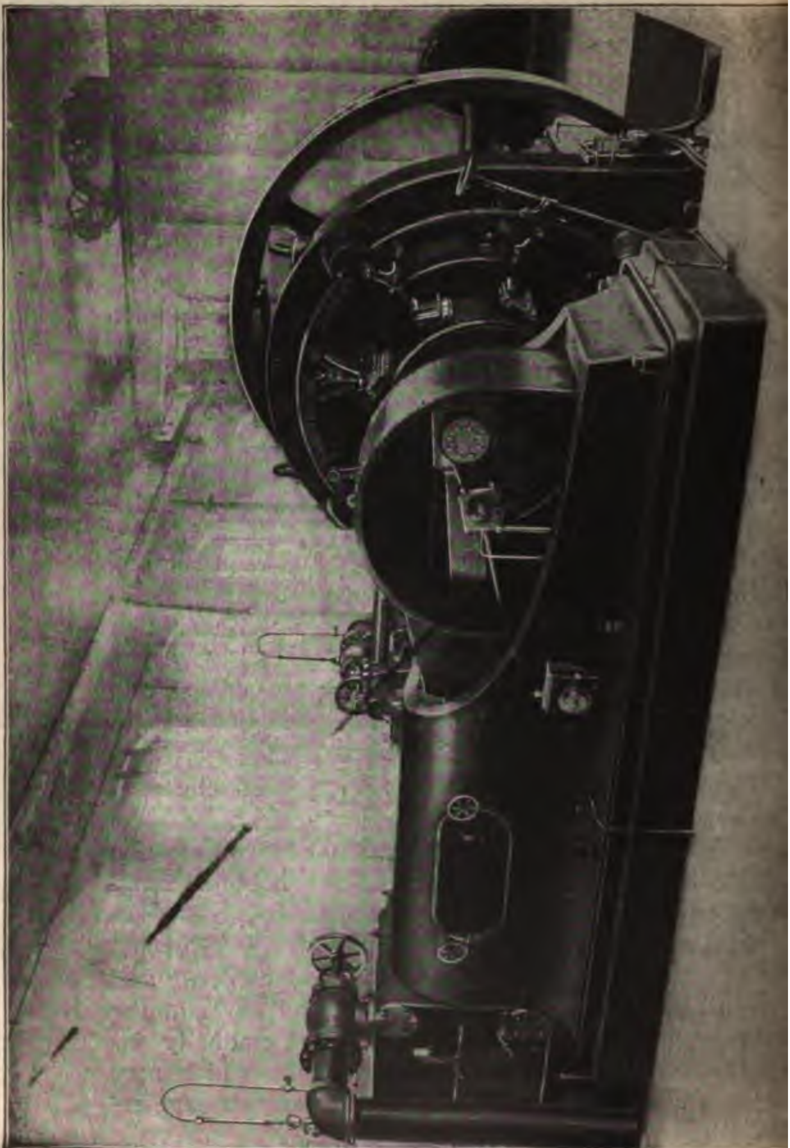
The first requisite in the installation of a dynamo, is to have a good foundation. With direct driven machines, the engine and dynamo should be mounted on the same bed-plate, whenever the size of the machine permits. Freedom from dampness and dust, as well as good ventilation should be carefully considered when selecting a location for a dynamo.

The dynamo should be placed far enough away from its driving pulley to allow the belt to have good contact, otherwise the belt will constantly slip, causing variations in the current, and when used for incandescent lighting, this will cause the lights to "wink."

The driving and driven shaft must be parallel, and the centers of the two pulleys in a line at right angles to the shaft.

Cleanliness.—The dynamo, as well as **all** electrical machinery, should be kept scrupulously clean, and the temperature of no part of the machine be allowed to rise so high as to make it uncomfortable to hold the hand against any part of the machine.

Operation.—The dynamo armature should be turned over slowly before starting, noting if it turns easily and if the brushes make proper contact at all parts of the revolution. The speed should be very **gradually** increased on starting up, so that any faults which may develop, can at once be remedied before any damage results.



Motor.—Before throwing the main switch for starting a motor, the starting resistance must always be included in the armature circuit. This should be gradually cut out as the motor comes up to speed.

Stopping.—In stopping a dynamo or motor, never throw any switch carrying a heavy current, but the machine should be allowed to gradually come to a stop, and not until then should the main switch be opened.

Brushes.—The position of the brushes should be such that the machine runs absolutely without sparks, and when a change of load causes sparking, the brushes should be at once shifted to the right position, as the commutator will become cut and so roughened if allowed to run long in this condition that it will soon have to be turned down with a cutting tool.

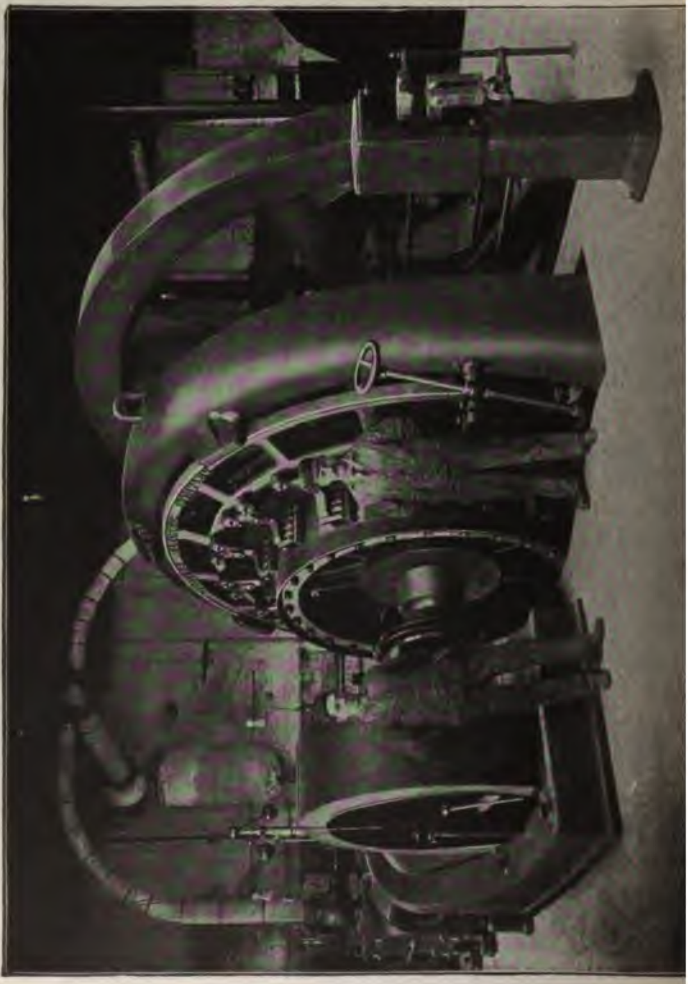
Causes of Sparking.—Sparking of the brushes may take the form of a vivid flash of light that hovers around the point of contact, or it may be intermittent.

There are a great many causes for sparking, the principal ones being as follows, viz.:

(1) Overload. (2) Brushes improperly set. (3) Brushes making improper contact. (4) Commutator rough or uneven. (5) Belt slipping. (6) Short circuit or reversed armature coil. (7) Too high speed. (8) High resistance of brushes. (9) Dirty brushes or commutator. (10) Vibration. (11) Worn commutator. (12) Grounds.

Failure of Dynamos to Generate.—This is due to **insufficient** residual magnetism in the field magnets. It only occurs when the dynamo is a new one, or when the field magnets have been taken apart for repairs. It seldom or ever occurs if the field magnets are **cast iron.**

Remedy.—It may be remedied by passing the current from a few storage cells for some time in the proper



direction through the **field coils**, but in practical work it is usual to charge the fields from an outside source. If the dynamo is run in multiple with another dynamo, it is only necessary to **lift** the brushes and throw in the main line switch, the same as is done to cut the machine into service. The fields in this way take a charge from the line, and their **polarity** will then be correct; that is, it will be the same as that of the other machine.

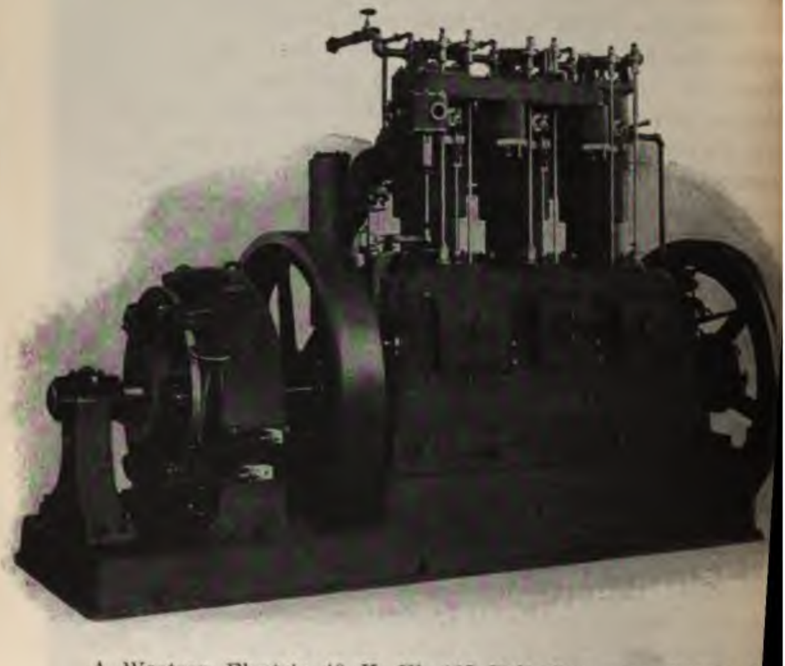
Failure to generate is also caused by the wrong **connection** of field or armature; from **open** circuits or **short circuits**, or from the field coils being incorrectly connected so that they **oppose** each other, thereby causing a **reversal** of the magnetism of polarity.

Under such conditions, the field coils produce a polarity opposed to the magnetism to which they owe their energy or strength, and therefore the machine will refuse to generate until the field connections are reversed; that is, the **polarity** in the pole pieces is corrected by sending a current from another machine through the field coils in the **proper** direction.

Alternating Current Machinery.—We have seen from Fig. 220 that when a coil is rotated within a magnetic field, that the opposite sides of the coil assist each other in the generation of an electrical pressure, and that therefore the E. M. F. is **double** that produced by a single conductor or rod.

By the operation of the coil rotated as shown, an alternating current is produced, and the apparatus for producing such a current is the simplest form of an alternating current machine, or alternator, as such a machine is usually called.

Essential Parts.—The coil is mounted so as to rotate between the north and south poles of a magnet. The ends of the coil are connected to two copper connecting



A Western Electric 40 K. W. 125 Volt Generator Direct C[on]nected to Gas Engine, Speed 290 R. P. M.
Fig. 249.

rings mounted on the shaft with the coil, but insulated from it. Upon each of these rings presses a stationary brush, which is kept always in contact with the rings and serves to **conduct** the current to an outside circuit.

Circuit.—A complete circuit is thus furnished from the brush through the external circuit to the other brush, where the collecting ring transmits it by means of its brush through the coil back to the first brush; and in this way the current continues to flow around this circuit as long as the coil is rotated.

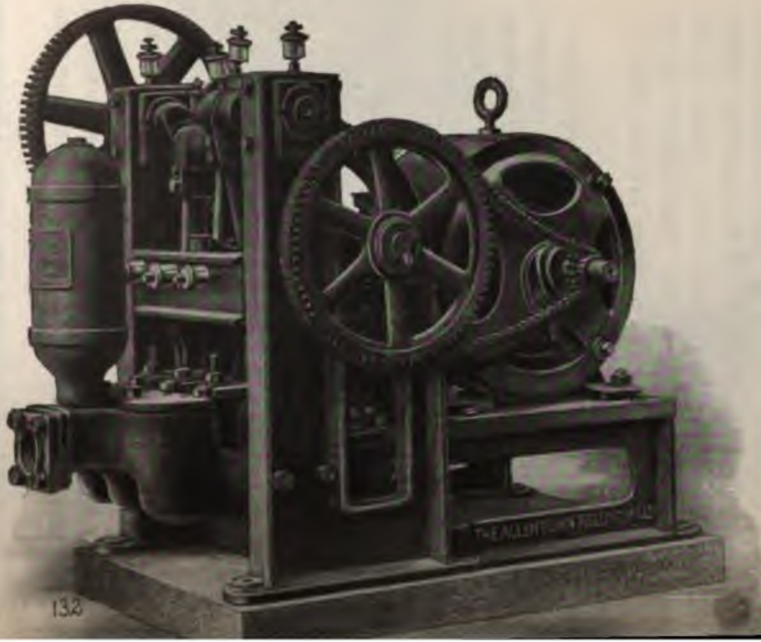
The alternating current produced by the rotation of the coil flows out to the external circuit in one direction during **one-half revolution** of the coil, but in an **opposite** direction during the remaining half of the revolution; and such flow of the current continues back and forth during each revolution of the coil.

The **strength** of the current rises and falls with these changes in the current, being greatest when the coil cuts the lines of force at right angles, which is when it lies in a horizontal plane, and is less when moving parallel with the lines of force, which is when it is in, or near, a vertical position.

Cycle.—These series of changes in a current, as is represented by the diagrams in Fig. 221 and 222, are called **cycles** or **periods**, and represent the current's strength, or E. M. F., during each complete revolution of a single coil in a bipolar field, i. e., a field having two poles.

In Fig. 221 (2) is represented **one** cycle, it being one complete revolution of the coil.

Alternation.—An alternation represents the change of a current during one-half of each revolution of the coil, and therefore **one** cycle is composed of **two** alternations.



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Frequency.—The number of cycles occurring per second is designated as the **frequency**, and is equal to the number of revolutions per second of a single coil in a bipolar field. For instance, if the coil makes 1800 revolutions per minute, the frequency will be 30 cycles per second, which is usually designated as simply 30.

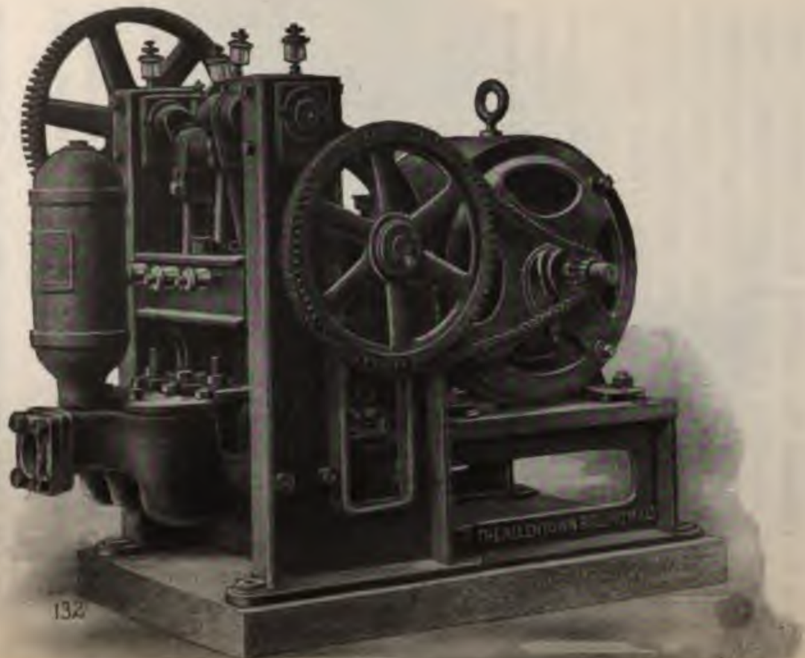
As each coil or conductor on the armature will pass through as many fields in each revolution as there are pairs of poles on the machine, the frequency of an alternator is therefore obtained by multiplying the number of revolutions per second by the number of pair of poles. For instance, an alternator having 10 pair of poles and making 900 revolutions per minute, will have a frequency equal to

$$\frac{900}{60} \times 10 = 150.$$

In Fig. 222 (1) is shown two separate coils placed in a magnetic field at right angles to each other. Instead of the commutator now being made in two halves or segments, it is composed of four segments, the two ends of each coil being connected to opposite segments. These segments must be insulated from each other so as not to short-circuit, and the two metalic brushes continue to press against the segments as before, they being at all times in contact with two segments diametrically opposite to each other, instead of with only one segment, as when but one coil of wire was used.

These brushes are connected to the external circuit the same as was done when only one coil was used.

In Fig. 222 (2) is shown a diagram of the fluctuations of the current when two coils are used. In this diagram the current produced by each coil is represented by a curve, making two curves in the diagram instead of only one curve as shown in Fig. 221 (2).


132

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It is seen from this that the **greater** the number of coils used, the **stronger** and more **uniform** becomes the current, so that by using a sufficient number of coils, the current can be made almost continuous. A continuous current of uniform strength is known as a **constant** current.

In such a current, the pulsations in the flow become almost unnoticeable, and it is therefore especially desirable for incandescent lighting and other work requiring a perfectly steady current.

It is therefore seen that a current when first produced by a dynamo or generator is an **alternating current,** the alternations extending back and forth over the entire circuit, and amounting to several thousand in a minute.

For incandescent lighting there should be at least a frequency of as much as 45 cycles per second, otherwise it will cause a **winking** in the lamps.

It has been further seen that in order to send the current out as a **direct** current, in which current the flow is always in the **same** direction, it is necessary that the current be changed upon the machine **before** transmission.

The addition of a **commutator** is required to make this change, and this practically is the **only** difference between a direct and an alternating current dynamo or generator.

Dynamo or Generator.—The word dynamo is derived from a Greek word, meaning **power,** while the word generator is derived from a word meaning **birth giving** and hence the two names are used interchangeably for electrical machines, though we usually speak of a dynamo when the current produced is to be used for **lighting**

generator when the current is to be used for power ɔoses in operating motors.

Neither of these electrical machines generate electy, but they only create the pressure to make it lable for power; as with air and water from which ner power nor work can be obtained without pres-. In the same way we cannot get the flow of an :ric current with the accompanying electrical energy ɔut pressure, and this pressure must be supplied by or the other of these electrical machines.

Contruction of the Armature.—The coil of wire vn in Fig. 220 and Fig. 221, is the simplest possible ı of an armature, and its revolution between the nets as has been shown, is the simplest form of a ımo or generator. The larger the number of loops greater the electrical energy gathered by the arma- and sent out over the circuit. The strength of the ent also depends upon the amount of magnetism in field coils, which take the place of the permanent ;net shown in the illustrations. These field coils ı the iron core about which they are wound, are nothmore than an electro-magnet, the construction and ration of which has already been described.

When the machine is first started up, that is the coil le to rotate, there is only what is known as the resil or natural magnetism in the iron, and therefore e are but few lines of force emanating from it, and current which is generated is therefore very slight.

As, however, the loop, or loops when more than one sed, passes through this magnetic field, it gathers a ll amount of electrical energy, which is made to pass ugh insulated wires wound around the magnetic s or pole pieces composing the fields, which at once ngthened the magnetism of the field, and this in turn

produces a greater electrical energy within the armature, which greater energy is again utilized to strengthen the influence of the magnet, and in this manner the machine is built up to its full capacity.

The armature is made up of a **number** of such coils wound about a soft iron core which serves to conduct the magnetic lines, all the coils being interconnected by means of the commutator which forms a part of the armature.

The armature is wound in a great number of ways, but the **drum** armature is the armature most generally used on account of its simplicity and comparative efficiency.

Drum Armature.—Such a type of an armature is shown in Fig. 223 and also Fig. 229. It will be seen in Fig. 229 that the wires are wound longitudinally, that is lengthwise, upon the cylinder or drum, and each loop of wire connected to the commutator as shown in Fig. 231.

The armature core is made up of sheet iron discs, these discs being insulated from each other, usually by a thin sheet of paper or other non-conducting material, in order to prevent the current from being **short circuited,** that is, instead of traveling the entire length of each loop, the current will jump across and take the shortest path from one connection to the other.

The circumference of these discs are provided with apertures for holding the armature coils in place. These apertures are shown in Fig. 229, which illustrates an armature in process of being wound.

Eddy Currents.—When an armature rotates in a magnetic field, the magnetism of its core is constantly **changing** as its parts pass through the different magnetic planes surrounding the poles.

When opposite a pole, the magnetism is at a mini-

mum, as that part of the armature is moving parallel with the lines of force and hence no magnetism is generated; but when the coils are moving at right angles to the lines of force, the magnetism is then at its maximum, but the lines then pass through the core in an **opposite** direction.

All parts of an armature core are therefore being continually magnetized in one direction, and then **demagnetized** as the parts pass into the opposite plane or magnetic field, and then magnetized again as the armature continues to rotate.

This magnetizing and demagnetizing of the armature as it passes each pole, continues as long as it rotates.

The loss resulting from the constant changes in the lines of force through the armature core is called **hysteresis**, which is from a Greek word meaning, "to lag behind."

This lagging behind of the lines of force is caused from their **opposition** to the changing of their direction of flow, that is, their tendency is to **maintain** any magnetic state which they have once acquired.

This constant changing of the direction of the lines of force, produces what is known as **eddy currents** in any solid mass of metal which is rotated in a magnetic field, or which is subjected to a **varying magnetic** field.

Such currents tend to flow in a circular path, and when produced in a large solid body they are very objectionable, as they not only consume a large amount of **energy**, but they also frequently cause a dangerous rise in the **temperature**, which may burn out the armature coils.

Prevention.—While it is impossible to entirely prevent the generation of these eddy currents, they can,

however, be prevented from attaining any considerabl[e] strength.

This is done by making the **core** of the armatur[e] **laminated,** that is, divided into a large number of thi[n] sheets, each sheet being insulated from the other by som[e] insulating material.

Armature cores are usually constructed, or **built up** as it is called, of thin sheet iron discs, as shown in Fig. 228, which discs are stamped out from soft sheet iron. These discs are insulated from each other usually by covering one face with varnished paper, or both faces are enameled.

Field Magnets.—Cast iron, cast steel and wrought iron are the principal materials used in the construction of the field magnets. These three metals have a very high **permeability,** by which is meant the conductivity for magnetic lines of force, or a measure of **ease** with which magnetism passes through any substance.

Saturation.—A metal can be **saturated** with mag-netism the same as a sponge is saturated with a liquid. In good iron the point of saturation is about 125,00[0] lines of force to the square inch of area of cross sec-tion, that is, that much area will absorb only that muc[h] magnetism.

When cast iron is used in the construction of fiel[d] magnets only about 45,000 lines of force to the squar[e] inch is allowed, while for wrought iron as much as 90-000 lines of force are allowed for this area. Therefor[e] when a small cross-section of core is desired, wroug[ht] iron is used, as its high permeability requires less cros[s] section area.

For convenience in handling, field coils are usuall[y] wound on a separate form or spool, as shown in Fig. 22[9] and these spools then placed on the cores or pole piece[s]

Ampere-Turns.—These windings of the wire upon the cast iron, wrought iron or cast steel field frames, are called **turns**, and the amount of magnetism produced in the fields by the passage of a current through these turns, depends upon the **number** of turns, and the **strength** of the current passing through them. Therefore, the product of the number of turns and the strength of the current passing through them expressed in amperes, is called the **ampere-turn.**

So far as the amount of magnetism is concerned, it s immaterial how the number of turns and the strength f the current are proportioned, as long as the **product** is he same.

That is, it makes no difference whether there are 10 irns with 3 amperes, or 15 turns with 2 amperes, as the roduct is 30 ampere-turns in each case.

Virtual E. M. F.—As the E. M. F. of an alternating irrent continually varies, rising and falling and revers- g its direction, there must be taken some **fixed unit** as standard measure to obtain its strength. As the E. . F. is equally effected in one direction as the other, value is therefore **independent** of the **direction** of the rrent, and the current can be regarded as acting in ly **one** direction in determining this standard of asurement.

No such trouble is experienced in finding the E. M. of a **direct** current, as it is a constant current and does t vary. Therefore, the alternating current must be asured by comparison with the direct E. M. F. and direct current. An alternating E. M. F. or current, iich produces the same deflection on an electrostatic ltmeter as produced by a direct E. M. F.; and an alter- ting current which produces the same **heating** effect

as a direct current, have the same value, and which value is known as the virtual E. M. F. and current.

This **virtual** value is equal to .707 of the **maximum** value. Therefore, an alternating E. M. F. having a maximum value of 150 volts, would have a **virtual** value only of $150 \times .707 = 106$ volts, or a current having a maximum value of 60 amperes, has only a virtual value of $60 \times .707 = 42.4$ amperes.

Self-Induction.—When a current flows through a wire, the wire becomes at once **surrounded** by whirls of magnetic lines, such as is shown in Fig. 218.

We have seen that by **coiling** the wire, this effect is greatly increased, and by supplying the coil with a soft iron core which acts as an electro-magnet, the effect is further greatly increased. But this self-induction in an alternating current tends to **restrain** the current when it is increasing, and in consequence prevents the current from obtaining its full strength.

The greater the amount of this self-induction in the circuit, the more is the strength of the current reduced. The effect of self-induction on an alternating current is therefore to **increase** the **apparent resistance,** and therefore requiring a greater E. M. F. at the terminals of the circuit than in the case with a non-inductive circuit.

This additional resistance of the circuit due to self-induction, is called **reactance** to distinguish it from the ohmic resistance of the conductor.

The combined effect of the reactance and the ohmic resistance, is called **impedance.**

In order, therefore, to find the value of an alternating current, the applied E. M. F. must be divided by the impedance of the circuit.

Now, when **two** coils are placed so that the magnetic whirl, or flux as it is called, of one coil passes

ırough the other coil, an E. M. F. is induced in the lat-
:r coil.

This requires the current in the first coil to vary or
ternate, as is always the case when an alternating
ırrent is used.

If the coils are supplied with an **iron core,** the re-
ıctance of the magnetic current through the coils will
e very much reduced, and in consequence the flux will
e much increased, thereby greatly increasing the **effi-
iency** of the apparatus.

It is alone upon this principle a transformer is con-
structed, which apparatus is nothing more than an in-
luction coil.

Transformer.—When an alternating current is used in one wire, it induces a current in an **adjacent** wire. This induction, however, takes place only during the period of an increase or decrease in the intensity of the current.

The coil to which the original energy is supplied is called the **primary** coil, while that in which the current is induced is called the secondary coil. On page 751 is shown the ordinary construction of a transformer.

The type of transformer here shown is what is known as the **Ruhmkoff coil,** and is intended to give a current of greater potential or higher voltage in the secondary coil than exists in the primary. It is what is technically called a **step-up** transformer, that is, one by which the voltage from the primary to the secondary current, is **increased,** the latter having more turns of wire.

Essential Parts of Transformers.—A transformer may be said to consist merely of a coil of wire placed within and carefully insulated from another coil. Within the inner coil there is a soft iron core, similar to that of an electro-magnet. In the practical transformer, this

core is made up of a number of plates or wires, and the entire apparatus is usually inclosed in a water proof case, in order that it may be placed out of doors so as to obviate the necessity for carrying the high tensile currents into a building.

Application of Transformers.—Next in importance to the discovery and utilization by Faraday of the lines of force for the production of an electric current, was the application of the induced current for the transmission with safety and through great distances of an electric current.

We have seen that the resistance of a circuit, or wire, to the passage of an electric current **increases** with its length, and that long lines require a stronger battery or current for their operation than do short ones. This increased resistance of long lines is one of the great obstacles to be overcome in the conveyance of an electric current over great distances. If the current is of low voltage, it does not have sufficient intensity to overcome the resistance of the line unless the resistance is made very low; and this low resistance cannot be obtained unless the wires are made very **large.** As these wires, or conductors, are usually made of copper, the excessive **cost** for such large wires would make their adoption impossible for practical purposes.

The other alternative for long distance transmission is the use of a **small** wire and a **high** voltage, but these high voltages cannot be used in ordinary electrical work as they are extremely dangerous, both from the standpoint of safety and danger from fires.

The means employed to overcome both of these serious difficulties is to use a small wire for the transmission of the current at an excessively high voltage, and then, at the point of utilization, insert a transformer

the circuit, by means of which the voltage can be :atly **decreased**, so that it can be used with **safety**, and **moderate** cost for any character of electrical work.

Should it be desired to send out a current of low ltage, and greatly increase it at the point of utiliza-n, a **step-up** transformer as it is called, is used. On : contrary should it be desired to send out a current high voltage and decrease it so as to be handled with 'ety inside of buildings, a **step-down** transformer is :n used.

The principle upon which these two types of trans-rmers act, is practically the same. The Ruhmkoff coils above described is a type of the so-called step-up ansformer. The only difference in their construction in the winding of the primary and secondary coils.

Multiphase Alternators.—An alternator which sup-ies only a **single** current to the external circuit is known ; a **single phase** machine, while one supplying **two** or **iree** currents is known respectively as a two and three-hase alternator, or **polyphase** or **multiphase** machine.

Two-Phase Alternators.—The number of currents o supplied to the external circuit, depends entirely upon he **armature** windings.

With a single phase machine, only about **one-half** 'f the surface of the armature is wound. Should an ad-ditional winding be placed on the armature in the space left vacant, then **two** separate and distinct currents can be supplied over the same circuit at the same time, and the alternator is then designated as a **two-phase** machine.

This additional winding between the original coils, generates a **maximum** E. M. F. when the other coils are not cutting the lines of force, and hence their E. M. F. is zero, but when these windings are at their **maximum**, then the added windings are at zero.

In Fig. 222 is shown the phase relation of the currents supplied by their two externals and independent circuits. The curve 1, represents the value of the current given by one armature circuit, and curve 2 represents that given by the other circuit.

In a two-phase alternator, when the circuits are independent, there must therefore be **four** external wires and **four** collecting rings.

Three-Phase Alternators.—In the same way the armature may be made to supply three separate and distinct currents to the external circuit, all differing in phase, i. e., **not in step.**

When the windings are all independent of each other, **six** wires will be then required, but usually the three windings are **combined** so as to require only **three** external wires.

In Fig. 222 is shown the value of the two currents in armature windings, in which diagram 1 and 2 represent the two respective currents, while 3 represents their **combination,** or the actual curve produced.

Rheostat.—This is a resistance that can be varied at will, usually consisting of a resistance, such as coils of wire, with connections at short intervals, terminating in metal contacts arranged in a circle, such as is shown in Fig. 234.

On inserting this resistance, or rheostat, between the field coil, connecting it usually in the **shunt** winding and one of the brushes, the current in the **field** coil can be perfectly controlled, and thereby the **voltage** of the machine.

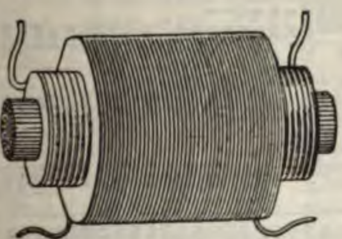
When the load increases and the effective voltage tends to drop, it is only necessary to **cut out** some of the resistance in the rheostat by moving the sliding contact piece, thus permitting **more** current to flow through the

creasing the magnetism, and thereby raising the of the machine.

this way the amount of resistance in series with l can be perfectly regulated at all times.

arity.—By this is meant the possession of poles, ›site properties, at opposite ends. This attrac-d repulsion possessed by all poles of a magnet nes the direction of flow of the current and the Hence, two or more electrical machines cannot be together unless their polarity is the same; other-ey will **resist** each other.

versing Polarity.—The simpliest way to change arity of a machine, is to raise the brushes and n the current from the other machine. The flow current through the fields, quickly reverses the of this machine, thereby making the polarity of machines the same.



A Transformer.

H. P.	Per ct. of Efficiency.	Watts.	16 c. p. 60 Watts lamps.	The top row indicates Volts. 50	75	110	220	400	500	600	800	1000	1200
½	75	497	8.2	10	6.62	4.5	2.25	1.24	1	.83	.62	.497	.41
¾	75	746	12.4	14.9	9.94	6.78	3.38	1.86	1.48	1.24	93	746	.62
1	75	995	16.6	20	13.24	9	4.5	2.5	2	1.66	1.24	1	.82
1½	80	1492	24.7	29.8	19.8	13.56	6.78	3.73	2.98	2.48	1.86	1.492	1.24
2	80	1865	31.1	37 3	24.9	16.9	8.5	4.7	3.8	3.1	2.33	1.9	1.6
3	80	2797	46.6	55.9	37.2	25.4	12.7	6.99	5.59	4.66	3.49	2.797	2.33
4	80	3730	62	74.6	49.8	33 8	16.9	9.3	7.5	6.2	4.66	3.8	3.1
5	80	4662	77.7	93.2	62.1	42.3	21.1	11.65	9.32	7.77	5.82	4.662	3.88
7½	90	6217	103	124	82 9	56.5	82.2	15.34	12.43	10.36	7 77	6.217	5 18
10	90	8288	138	165	110	75.3	37.6	20.72	16.57	13.81	10.36	8.288	6.9
15	90	12433	207	248	165	113	56.5	31.08	24.86	20.72	15.54	12.43	10.36
20	90	16578	276	331	221	150	75.3	41.44	33.15	27.63	20.72	16.57	13.98
25	90	20722	345	414	276	188	94.1	51.8	41.6	34.5	25.9	20.7	17.2
30	90	24866	414	497	331	226	113	62	49.7	41.4	31	24.8	20.7
40	90	33155	552	663	442	301	150	82.8	66.3	55.2	41.4	33.1	27.6
50	90	41444	690	828	552	376	188	103	82.8	69	51 8	41.4	34.5
60	90	49733	828	994	663	452	226	124	99.4	82.8	60	49.7	41.4
70	90	58022	967	1160	773	527	263	145	116	96.7	72.5	58	48.3
80	90	66311	1105	1326	884	602	301	165	132	110	82.9	66.3	55.2
90	90	74599	1243	1491	994	678	339	186	149	124	93	74.5	62
100	90	82888	1381	1657	1105	753	376	207	165	138	103	82.8	69
120	90	99459	1657	1989	1326	904	452	248	198	165	124	99	82.8
150	90	24312	2072	2486	1657	1131	565	310	248	207	155	124	103

Amperes per Motor.

Table No. 19.

Brown & Sharpe	Diameter.		Square of Diameter.	Sectional Area.	Safe Carrying Capacity in Amperes.				Weight.				Length.		Resistance of Pure Copper Wire at 75 Degrees F. (23.89 Deg. Cent.)			
							Chicago Code.		Bare.		Weatherproof Insulation		Bare.	Weatherproof Insulation.				
No.	Mils.	Millimetres.	Circular Mils.	Square Millimetres	National Code.	New England Code.	Concealed Work.	Open Work.	Pounds per 1,000 Feet.	Pounds per Mile.	Pounds per 1,000 Feet.	Pounds per Mile.	Feet per Pound	Feet per Pound.	Ohms per 1,000 Feet.	Ohms per Mile.	Feet per Ohm.	Ohms per Pound.
0000	460.000	11.684	211600.0	107.219	175	300	218	312	639.33	3359	758	4000	1.6	1.25	.04906	.25903	20383	.000076736
000	409.640	10.405	167805.0	85.028	145	245	181	262	507.01	2663	606	3200	2	1.75	.06186	.32664	16165	.00012039
00	364.800	9.266	133079.4	67.431	120	215	150	220	402.09	2112	492	2600	2.5	2	.07801	.41187	12820	.00019423
0	324.950	8.254	105592.5	53.504	100	190	125	185	319.04	1661	385	2036	3.2	2.50	.09831	.51909	10409	.00030772
1	289.300	7.348	83694.2	42.409	95	160	105	156	252.88	1328	308	1628	4	3.25	.12404	.65490	8062.3	.00048994
2	257.630	6.544	66373.0	33.632	70	135	88	131	200.54	1069	250	1310	5	4	.15640	.82582	6393.7	.00078045
3	229.420	5.827	52634.0	26.670	60	115	75	110	259.03	835	201	1060	6.3	5	.19723	1.0414	5070.2	.0012406
4	204.310	5.189	41742.0	21.151	50	100	63	92	126.12	662	163	862	8	6	.24869	1.3131	4021.0	.0019721
5	181.940	4.621	33102.0	16.773	45	90	53	77	100.01	526	134	706	10	7.50	.31361	1.6558	3188.7	.0031361
6	162.020	4.115	26250.5	13.301	35	80	45	65	79.32	417	110	577	12.6	9	.39546	2.0881	2528.7	.0049868
7	144.280	3.665	20816.0	10.548	30	67	..	..	62.90	330	90	475	16	11	.49871	2.6331	2005.2	.0079294
8	128.490	3.264	16509.0	8.366	25	60	33	46	49.80	262	74	392	20	13.50	.62881	3.3201	1590.3	.012608
9	144.430	2.907	13094.0	6.635	..	50	..	..	39.56	208	62	328	25	16	.79281	4.1860	1261.3	.020042
10	101.890	2.588	10381.0	5.260	20	40	25	32	31.37	165	52	275	32	19	1.	5.2800	1000.0	.031380
11	90.742	2.305	8234.0	4.172	..	35	..	..	24.88	131	44	231	40	22.75	1.2607	6.6568	793.18	.050682
12	80.808	2.053	6529.9	3.309	15	30	17	23	19.73	103	36	193	51	27.25	1.5898	8.3940	629.02	.080585
13	71.961	1.828	5178.4	2.618	..	26	..	..	15.65	82	31	162	64	32.50	2.0047	10.585	498.83	.12841
14	64.084	1.628	4106.8	2.081	10	22	12	16	12.41	65	26	135	81	39	2.5908	13.680	385.97	.20880
15	57.068	1.450	3256.7	1.650	..	18	..	..	9.84	51.5	21	111	102	47.50	3.1150	16.477	321.02	.31658
16	50.820	1.291	2582.9	1.309	5	15	..	..	7.81	41	18	96	129	55	4.0191	21.221	248.81	.51501

Table No. 20.

No. of Wire Gauge.	American or Brown & Sharpe.	Birmingham or Stubs.	Washburn & Moen Manufacturing Co. Worcester, Mass.	Trenton Iron Co., Trenton, N. J.	New British.	Old English from Brass Mfr's. List.	No. of Wire.	No. of Wire Gauge.	American or Brown & Sharpe.	Birmingham or Stubs.	Washburn & Moen Manufacturing Co. Worcester, Mass.	Trenton Iron Co., Trenton, N. J.	New British.	Old English from Brass Mfr's. List.	No. of Wire.
000000	......	......	.46	......	......	......	000000	18	.040303	.049	.047	.045	.048	.049	18
00000	......	......	.43	.45	......	......	00000	19	.03589	.042	.041	.039	.04	.04	19
0000	.46	.454	.393	.4	.4	......	0000	20	.031961	.035	.035	.034	.036	.035	20
000	.40964	.425	.362	.36	.372	......	000	21	.028462	.032	.032	.03	.032	.0315	21
00	.3648	.38	.331	.33	.348	......	00	22	.025347	.028	.028	.27	.028	.0295	22
0	.32495	.34	.307	.305	.324	......	0	23	.022571	.025	.025	.024	.024	.027	23
1	.2893	.3	.283	.285	.3	......	1	24	.0201	.022	.023	.0215	.022	.025	24
2	.25763	.284	.263	.265	.276	......	2	25	.0179	.02	.02	.019	.02	.023	25
3	.22942	.259	.244	.245	.252	......	3	26	.01594	.018	.018	.018	.018	.0205	26
4	.20431	.238	.225	.225	.232	......	4	27	.014195	.016	.017	.017	.0164	.01875	27
5	.18194	.22	.207	.205	.212	......	5	28	.012641	.014	.016	.016	.0148	.0165	28
6	.16202	.203	.192	.19	.192	......	6	29	.011257	.013	.015	.015	.0136	.0155	29
7	.14428	.18	.177	.175	.176	......	7	30	.010025	.012	.014	.014	.0124	.01375	30
8	.12849	.165	.162	.16	.16	......	8	31	.008928	.01	.0135	.013	.0116	.01225	31
9	.11443	.148	.148	.145	.144	......	9	32	.00795	.009	.013	.012	.0108	.01125	32
10	.10189	.134	.135	.13	.128	......	10	33	.00708	.008	.011	.011	.01	.01025	33
11	.090742	.12	.12	.1175	.116	......	11	34	.006304	.007	.01	.01	.0092	.0095	34
12	.080808	.109	.105	.105	.104	......	12	35	.005614	.005	.0095	.009	.0084	.009	35
13	.071961	.095	.092	.0925	.092	......	13	36	.005	.004	.009	.008	.0076	.0075	36
14	.064084	.083	.08	.08	.08	.083	14	37	.004453	......	.0085	.00725	.0068	.0065	37
15	.057068	.072	.072	.07	.072	.072	15	38	.003965	......	.008	.0065	.006	.00575	38
16	.05082	.065	.063	.061	.064	.065	16	39	.003531	......	.0075	.00575	.0052	.005	39
17	.045257	.058	.054	.0525	.056	.058	17	40	.003144	......	.007	.005	.0048	.0045	40

Difference Between Wire Gauges in Decimal Parts of an Inch.

Table No. 21.

CHAPTER XXVII.

ELEVATORS.

Definition.—The term elevator is applied to that ıss of hoisting machinery used to raise and lower a ge, car, plattorm, etc., between fixed landings.

In many foreign countries they are designated as ifts."

Principal Parts.—The following are their principal .rts: (1) The motor. (2) The car, cab, etc., with ıides and counterbalance weights. (3) The trans-ission device. (4) The controlling devices. (5) The fety devices.

Classification.—The classification of elevators is ade according to the **motive** power used for their op-ation, the most common classes, or types, being hand ɔwer elevators, steam elevators, belt elevators, hydrau-c elevators and electric elevators.

Counterbalancing Weights.—In all elevators, regard-ss of the type, the weight of the car is **counterbalanced,** o that its entire weight and fixtures is not a dead weight, ut only the **difference** between the weight of the car nd the counterweight.

It is usual to attach the counterweight to the car by means of a separate rope which is lead over one or more overhead sheaves.

The counterweight must be **lighter** than the weight of the empty car and fixtures, so that the car may de-scend when empty by its own weight, and the power necessary to raise the car must then be only sufficient to aise the load, plus the **unbalanced** weight.

Overbalanced.—When the power must be applied uring **both** the up and the down trip, the car is said to : **overbalanced.** This is usually done in all **drum** ele-

vators, they being made with the motor and drum **reversible.**

Counterweights.—These are generally made of cast-iron blocks, carried in a frame and guided by suitable guideways. The guides are usually made of T iron, though wood is sometimes used.

Chains.—To avoid the extra weight of ropes in high buildings, balancing chains are often used, which are hung from the bottom of the car.

Controlling Devices.—Such devices consist essentially of some form of **power** control, as a **wheel** or **lever**, and a **brake.** The **shipper rope** which passes through the car and is connected to the controlling motor, is the simplest form of motor control. As a delicate adjustment cannot be obtained with such a control, and as such a rope is also dangerous from any broken strands which may catch in the passage of the rope through the hand of the operator, this form of control is not now generally used.

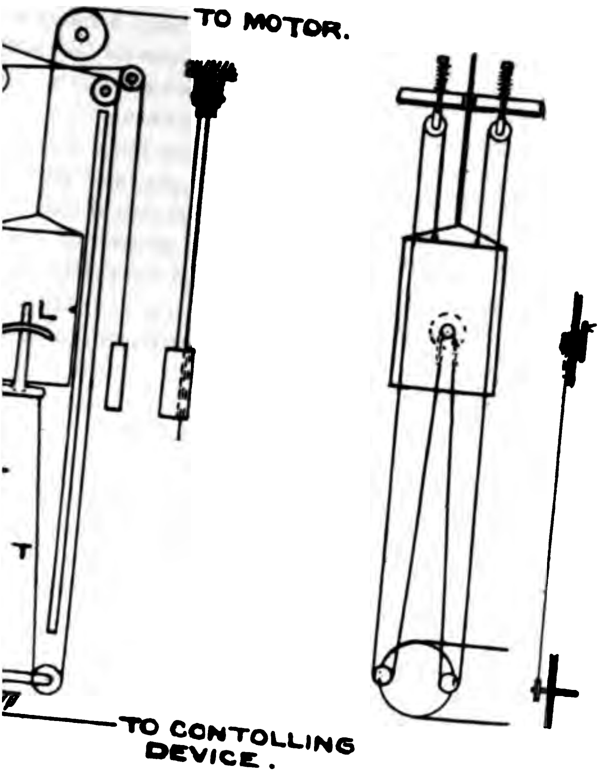
In order to overcome these objections various devices are used for changing the motion of a shipper rope into the motion of a lever or crank.

In Fig. 251 is shown two of the most generally used control devices.

In the arrangement shown in (1) there is a three-arm lever L in the car, the long arm of which is moved to the right or left by the operator, according as he desires the car to go up or down.

To each of the shorter arms is connected a rope T running down and over an idler carried by another three-arm lever R, which is pivoted at the bottom of the hoistway. The arrangement and operation of the ropes can be clearly seen from the diagram.

The arrangement shown in (2) is the usual oper-



2

Elevator Control Devices.
Fig. 251.

ating device employed by the Otis Elevator Company on their hydraulic lifts.

In this arrangement it will be noticed a **hand-wheel** is substituted for the lever. Such a device is called a **hand-wheel controller,** while the control shown in the first diagram, is known as **lever-controllers.**

Electric Controllers.—Such controllers consist of combinations of switches and resistances, and while they serve the same purpose as the mechanical controllers above described, their operation is altogether different as will be seen from their description hereafter given.

Safety Devices.—Such devices are usually divided into **two** classes, viz.: (1) Those that control the **motive power** itself, which are called Motor Safeties, and (2) Those that control the operation of the car, which are called **Car Safeties.**

Limit Stops.—The most generally used safety device of the first class, or motor safeties, is the **limit stop.** This consists of two knobs, or buttons, so placed on the shipper rope that should the operator fail to stop the car when the car reaches the limit of its travel, it will strike against one of these knobs, or buttons, and thus automatically operate the **shipper sheave,** thereby stopping the car before doing any damage. These buttons are placed **both** at the top and bottom limit of the travel of the car, so as to shut off the power should the operator fail to do so, either in going up or coming down with the car.

Owing to liability of these buttons slipping or breaking, they are no longer relied upon for safety, but are only used as an additional precaution to the limit stop which is placed on the motor itself.

Limit Stops on Motors.—For drum elevators, the limit stops are usually constructed as follows: A screw

read is cut on a continuation of the drum shaft, and a ar-wheel, the hub of which forms a nut, is placed on e threaded portion of the shaft. This gear-wheel shes with another gear-wheel bolted to the shipper eave. The hub of the wheel has claws on either side, rresponding to similar claws formed on two other nuts at are clamped securely to the drum shaft.

When the wheel travels either way, it will eventlly be engaged by one or the other of the revolving ts and be swung around carrying with it the shipper eave, with the effect of cutting off the power and apring the brake.

Slack Cable Safety.—It often happens that the eletor car is obstructed in its descent by gummy guides, or e car is hastily stopped by the operator, causing the ble to continue to pay out as the motor continues to n.

This may permit the car to drop; or should it be sting on the bottom of the hoistway, the slack cable ay cause considerable damage by getting into the revlving parts of the machine.

To provide against such an emergency, elevators e generally equipped with a safety device called a **slack ble safety.**

Such a device consists of an idler which travels axilry on its shaft with the hoisting rope along the drum. he shaft is supported on levers which are pivoted in a onvenient manner. A cord leads from the arm of the ver over sheaves to a bell-crank, one arm of which is eighted, while the other engages a clutch. As long as he hoisting rope is taut, the idler is pushed outward gainst the weight of the bell-crank; but should the oisting rope become **slack**, the weight on the bell-crank ill cause the clutch to engage the gear-wheel mounted

loosely on the drum shaft, causing the same to revolv with the drum shaft. The gear-wheel meshes with an other gear-wheel fastened to the shipper sheave, turning the latter around as the hoisting cable becomes slack and in this way the **power** is cut off by the stopping of the motor.

Legislation.—Owing to the great height of modern buildings, and the high speed with which passenger ele vators must be **run**, there should be a **monthly** inspec tion made of all passenger elevators, and especially of al **safety devices** on same.

To insure such an inspection, the owner of the ele vator should be required to have the same made by a duly authorized official, under a heavy penalty for failure to do so.

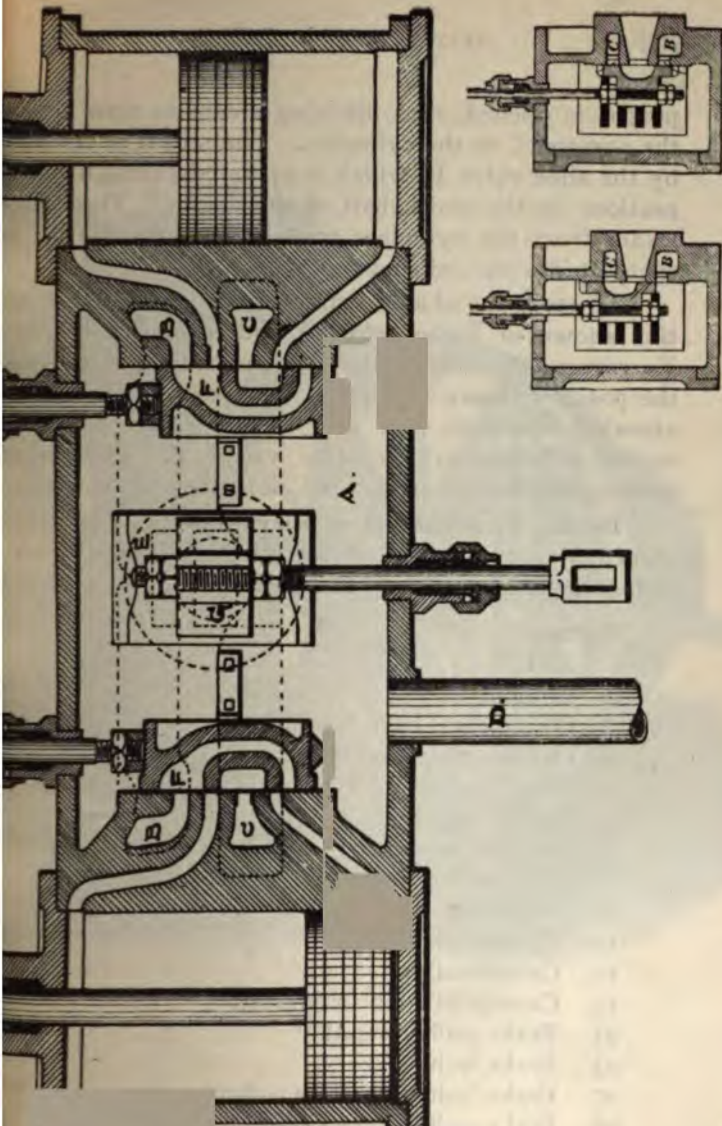
Belt Elevators.—Such elevators are driven directl from **line-shafting.** They are therefore generally use only for **freight service.**

Steam Elevators.—Until recently this was the mos popular type of elevator owing to its reliability and effi ciency. It still is favored by many users, though it i hardly probable that it will ever be adapted to the con stantly increasing modern requirements.

Construction.—The engines used for their operation are duplex engines of the vertical type.

Both the slide valve and piston valve are used b manufacturers, but the slide valve is preferable. Owin to the necessity of prompt starting, stopping and rever ing the engine, the engines are made duplex. The stea valve used is known as a **reversing valve,** the constru tion of which is fully shown in Fig. 252.

Steam Cylinder for Crane Reversing Engine.— Steam enters at D and fills the chest A. If the chang valve E is moved to the position shown in Fig. 1 th



Steam Reversing Valve.
Fig. 252

28. Drum stand cap.
29. Driving pinion.
30. Internal gear.
31. Drum.
32. Brake weight.
33. Brake lever and roller.
34. Brake cam.
35. Right and left connection.
48. Automatic stop worm wheel and pinion (covered).
49. Slack cable lever.
50. Slack cable lever link.
51. Slack cable reversible shaft.
52. Slack cable bracket for reversible shaft.
53. Slack cable, arms and slats.
54. Brake crank.
55. Brake blocks or wood.
56. Brake band.

The above parts are given for a fuller underst of the automatics.

These elevators are usually **overbalanced** when with **worm-gearing**, but like belt elevators are not balanced when made with **spur-gears.**

Hydraulic Elevators.—This is regarded as the safe type of elevators, especially for high lifts and speeds.

The simplest form **is the** direct acting or pl elevator, but this form is not as generally used **piston** type of this elevator.

The most serious objection to the plunger el is the large amount of **space** required for its oper and also the large **volume** of water required. T due to the hydraulic cylinder and plunger having a **equal** to the lift.

n the piston elevator, the hydraulic cylinder can be much shorter by introducing multiplying sheaves.

lunger Elevator.—The plunger elevator is conform- for either passenger or freight service and has a degree of efficiency, due to the fact that the power rted direct without the intervention of sheaves or . The car is always supported from beneath by unger, and therefore there is no necessity for pro- g it with the safety appliances used on the car in types of elevators. Owing to the fact that a cylin- f a length equal to the car travel must be sunk in ound, the nature of the soil has a considerable bear- pon the cost of the installation.

'or passenger service, plunger elevators are built travels as high as 225 feet and with speeds as great o feet per minute. For freight service, they are with a lifting capacity up to 80,000 pounds.

Iydraulic Plunger Elevator.—The Otis Pulling ger Type of Hydraulic Elevator differs from any in the respect that when **lifting** the load it does not me water, but **discharges** it from the cylinder.

n this elevator the weight of the plunger itself, is of solid steel, lifts the load, the plunger descend- nto the cylinder as the car rises in the hatchway. the operation is reversed and the car descends, the is pumped up to the required pressure and, assisted e weight of the car, raises the plunger and the car nds.

'his elevator was designed to meet the requirements gh buildings, and on account of its economy in op- n, very high speed, and the extreme rapidity with stops and starts can be made, ranks high among ulic elevators.

As this machine is operated under a medium pressure, rarely exceeding 250 pounds per square inch, it is possible to use the compression-tank system.

The compression tank is usually placed in the basement and the discharge tank either on the roof or in any convenient location at least as high as the top of the cylinder, so that the cylinder is always filled with water, thereby acting as a safety brake.

Piston Type.—There are two types of the piston elevator in general use, viz.: (1) The vertical, and (2) The horizontal type.

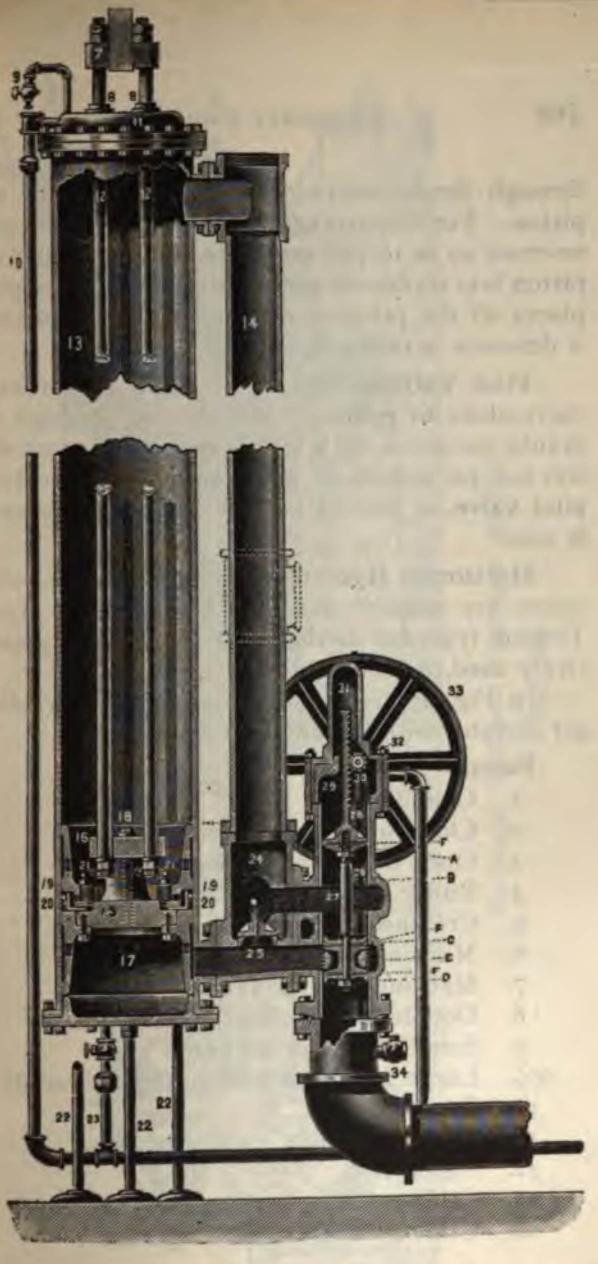
Vertical Hydraulic Piston Elevators.—Where space is limited, this is the preferable type as it is always easier to obtain head-room, than it is floor space.

Construction.—In Fig. 254 is shown the parts and general construction of this type of elevator.

Controlling Device.—The controlling device consists of a balanced three-way valve operated by a shipper rope in the usual manner.

The action of the motor under its control is as follows: The space of the cylinder above the piston is always under water pressure, the supply pipe being directly connected with a space through the circulating pipe. The other end of the circulating pipe is connected between the two valve pistons in the valve chamber. If the valve pistons be moved downwards, so as to bring the upper valve chamber, and in this way the space of the cylinder above the piston, into communication with the space below the piston, there will be the same water pressure on both sides of the piston.

Thereupon, the car being heavier than the piston with the counterweights, will cause the latter to ascend, while the car itself is descending, and by which operation the water from above the piston will be forced



e Otis Vertical Hydraulic Passenger and Freight Machine.

Fig. 254.

through the circulating pipe into the space un piston. For the ascent of the car, the valve pist reversed so as to put the space of the cylinder be piston into communication with the discharge pipe places all the pressure on the top of the piston, it descends it raises the car.

Pilot Valves.—Instead of using the ordinar valve alone to guard against shocks; for high sp draulic elevators, by which is meant elevators tha 600 feet per minute or more, an **additional** valve **pilot valve,** or auxiliary valve as it is sometimes is used.

Horizontal Hydraulic Piston Elevators.—Th vators are usually made (1) Compression type, Tension type, but as the latter type is now almos sively used, it alone will be considered.

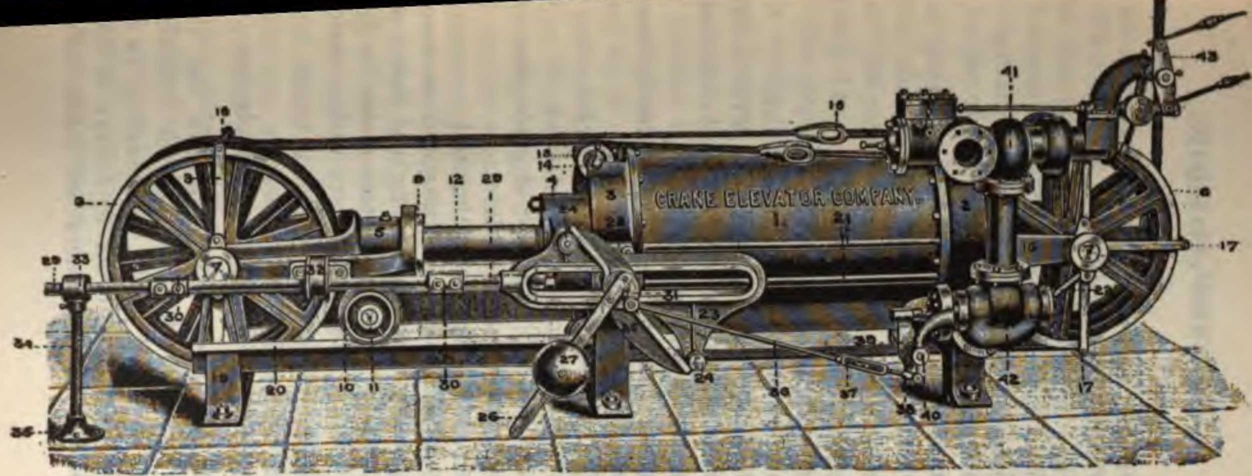
In Fig. 255 is shown a horizontal hydraulic ger elevator with the different parts.

Parts.—

1. Cylinder.
2. Closed or back cylinder head.
3. Open or front cylinder head.
4. Buffer.
5. Crosshead.
6. Machine sheaves.
7. Machine sheaves shafts.
8. Double or crosshead cable guards.
9. Small or crosshead buffer ring.

9½. Large or piston buffer ring (covered).

10. Carwheel.
11. Carwheel shaft.
12. Piston rod.
13. Cable roller.
14. Cable roller shaft and oil cup.



Horizontal Hydraulic Passenger Machine.

Fig. 255.

15. Cylinder drawbars and clevises.
16. Cylinder head arms.
17. Triple or blackhead cable guard.
18. Guard rods and pipes.
19. Guide rail stand.
20. Guide rails.
21. Buffer bolts.
22. Cylinder arm brace.
23. Automatic stop tappet.
24. Automatic stop cam rollers.
25. Automatic stop cam.
26. Automatic stop cam balance lever.
27. Automatic stop cam balance lever weight.
28. Automatic stop front head bracket or cam s
29. Automatic stop tappet rod.
30. Automatic stop tappet rod clamp button.
31. Automatic stop tappet roller.
32. Automatic stop crosshead bracket.
33. Automatic stop tappet rod guide.
34. Automatic stop tappet rod guide pipe.
35. Automatic stop floor plate.
36. Automatic stop connecting rod.
37. Automatic stop connecting rod turnbuckl
38. Automatic stop connecting rod fork end.
39. Automatic stop valve stem rocker or leve
40. Automatic stop valve stem rocker shaft.
41. Auxiliary change valve.
42. Automatic stop valve.
43. Rocker arm with drawbar and clevises.

Construction.—Both the fixed and the trav sheaves are located at the front of the cylinder, t sheaves being mounted in the crosshead at an ang the horizontal plane. In order to occupy as little space as possible the cylinders are made very s

hich necessitates a high ratio of the transmitting devices. This ratio is generally chosen as 10:1, by which meant that for every 1 foot that the piston moves, the ar will travel a space of 10 feet. After the automatics o into operation the car should run five or six feet to void the jar of a too sudden stop.

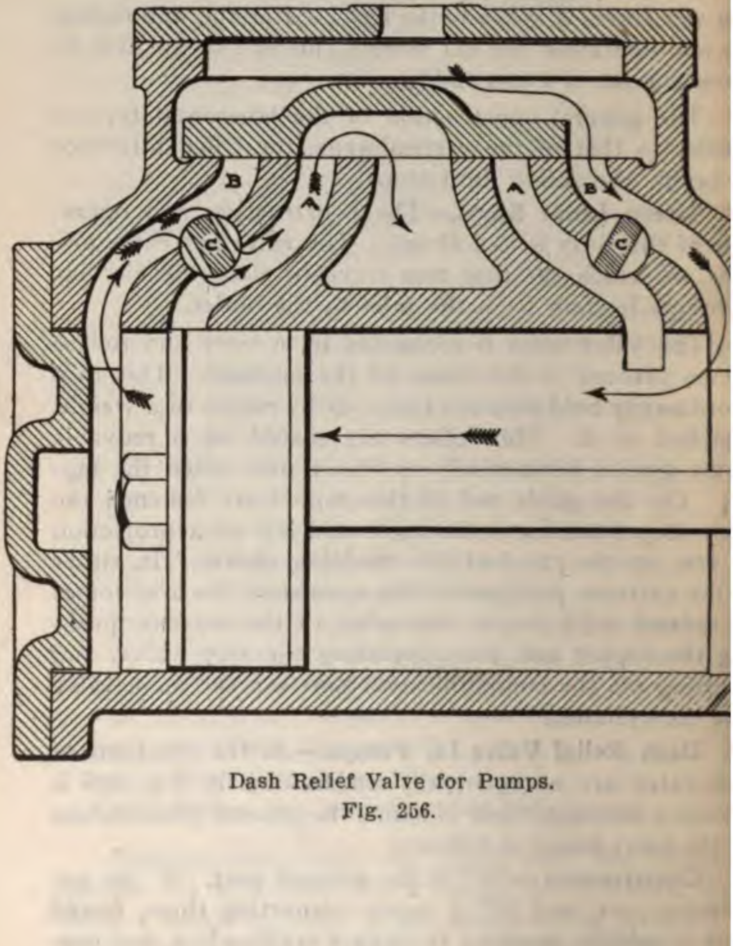
The general construction of the horizontal type is imilar to that of the vertical type, the chief difference eing in the safety limit stops.

Safety Limit Stops.—The construction and operaion of this stop is as follows: The valve has three pisons, of which the first two serve to close the circular penings leading from the inlet to the outlet.

The valve stem is connected by a lever and rod to cam pivoted to the frame of the machine. This cam s ordinarily held between two rods by means of a weight ttached to it. The rollers are placed on a movable frame guided horizontally as shown and called the tappet. On the guide rod of this tappet are fastened the limit stop buttons to the right and left of a projection or arm on the cross of the traveling sheave. In either of the extreme positions of the crosshead, the arm comes in contact with one or the other of the buttons, pushing the tappet and thus operating the stop valve, and hutting off the communication between the main valve nd the cylinder.

Dash Relief Valve for Pumps.—As the functions of his valve are not generally understood, in Fig. 256 is hown a sectional view of same, the general construction f the valve being as follows:

Construction.—"A" is the exhaust port, "B" the adission port, and "C" a valve connecting them, fittted ith a spindle, working through a stuffing-box, and conolled from the outside of the cylinder by a hand-wheel,



Dash Relief Valve for Pumps.
Fig. 256.

it will be seen that when the piston travelling in the di-
rection indicated covers the opening of the exhaust port
as shown, the volume of steam remaining in the cylinder
can no longer escape if the relief valve is closed, but
immediately forms a **cushion**, whereas if the relief valve
s open as shown in sketch, the steam flows by the ad-
mission port through the relief valve to the exhaust port,
and the piston continues its stroke.

In this way the amount of steam cushioned can be
egulated by adjusting the relief valve, and perfect con-
rol over the length of the stroke can be maintained.

HOW TO PACK HYDRAULIC VERTICAL CYLINDER ELEVATORS, AS GIVEN BY THE MANUFACTURERS.

Packing Vertical Cylinder Piston from Top.—Run
the car to the bottom, and close the gate valve in the
supply pipe. Open the air cock at the head of the cylin-
der, and also keep open the valve in the drain pipe from
the side of the cylinder long enough to drain the water
in the cylinder down to the level of the top of the piston.
Now remove the top head of the cylinder, slipping it up,
the piston rods out of the way, and fasten there. If the
piston is not near enough to the top of the cylinder to
e accessible, attach a rope or small tackle to the main
ables (not the counterbalance cables), a few feet above
he car, and draw them down sufficiently to bring the
iston within reach. Remove the bolts in the piston
ollower by means of the socket wrench furnished
or that purpose. Mark the exact position of the piston
ollower before removing it, so that there will be no dif-
iculty in replacing it. On removing the piston follower
you will find a leather cup turned upwards, with coils
of 5/8 inch square duck packing on the outside. This you

will remove and clean out the dirt, also clean out the holes in the piston, through which the water acts upon the cups. If the leather cup is in good condition, replace it, and on the outside place three new coils of ⅝ inch square duck packing, being careful that they break joints, and also that the thickness of the three coils up and down does not fill the space by ¼ inch, as in such case the water might swell the packing sufficiently to cramp it in this space, thus destroying its power to expand. If too tight, strip off a few thicknesses of canvas. Replace the piston follower, and let the piston down to its right position. Replace the cylinder head, and gradually open the gate valve in the supply pipe, first being sure that the operating valve is on the center. As soon as the air has escaped, close the air cock and the elevator is ready to run.

Packing the Vertical Cylinder Valves.—To pack the valve run the car to the bottom and close the gate valve in the supply pipe. Then throw the operating valve for the car to go up, open the air cock at the head of the cylinder, and the valve in the drain pipe at the bottom, and the water will drain out of the cylinder. When the cylinder is empty, reverse the valve for the car to run down, so as to let the water out of the circulating pipe. In cases of tank pressure, where the level of the water in the lower tank is above the bottom of the cylinder, the gate valve in the discharge pipe will have to be closed as soon as the water in the cylinder is on a level with that in the tank, allowing the rest to pass through the drain pipe to the sewer. As soon as the water has all drained off, take off the valve cap and remove the pinion shaft and sheave, marking the position of the sheave and the relation which the teeth on the pinion bear to the teeth on the rack before removing. You can now take out the valve plunger, and put the new packings on in

the same position as you find the old ones. Replace all the parts as first found.

Before refilling the cylinder, close the valves in the drain pipes, but leave the air cock at the head of the cylinder open, and be careful that the operating valve is in position for the car to go down. Gradually open the gate valve in the supply pipe. When the cylinder has filled with water and the air has escaped, close the air cock and open the gate valve in the discharge pipe.

Packing Horizontal Hydraulic Elevators.—Run the car to within one foot of the extreme top and secure it to the overhead beams with chain or rope. Close the gate valves in the supply and discharge pipes and open the air cock in the small pipe leading to the valve. Then draw the water from the cylinder by opening the stop cock in the drain pipe leading from below the supply elbow. Now remove the buffer across the front end of the cylinder and slide it along the piston rod out of the way. Remove the follower by taking off the nuts. With a hooked piece of wire take out the old packing. Raise the piston head up till it is in the center of the cylinder. If the cylinder is found to be in good condition, cut off four rings of one inch square lubricated fibrous packing nine inches longer than the circumference of the cylinder. Place the two ends of a ring together and form tucks with the balance. Force these tucks in, one at a time, with a hard wood stick until all is level against the head. Proceed in same manner with remainder of packing. So arrange packing that the joints in the different rings do not come together. If the cylinder is badly worn, use square pure rubber packing for the first and last ring and make the rubber rings but one inch longer than the circumference of the cylinder. This rubber insures a backing for the fibrous packing. After putting

packing in position, replace the follower and screw the nuts on with the fingers, until the follower is close against the packing. On two of the studs opposite each other will be found jam nuts. Set these out against the follower and tighten with a wrench. Replace the buffer and draw the large nuts up tight. Close the drain cocks and shift the operating valve for going up. Open the gate valve in the supply pipe and fill the cylinder. When cylinder is filled close the air cock. As the car in the first place was not at the extreme top, the pressure in the cylinder will run the piston head up against the machine buffer and the car will ascend to the extreme top. The fastenings may then be removed. Throw the operating valve on the center and open the discharge. The elevator is then in readiness to descend. Do not make any trips until the cylinder is thoroughly greased. Continue greasing twice a week.

In the course of time leaks will occur in the cylinder. Loosen the jamb nuts back of the follower and set up the nuts on the studs equally until the leak is stopped. Then retighten the jamb nuts.

Otis Gravity Wedge Safety.—1. **Under the car** is a heavy **hardwood safety plank,** on each end of which is an iron adjustable jaw, enclosing the guide on the guide post. In this jaw is an iron wedge, withheld from contact with the guide in regular duty. Under the wedge is a rocker-arm, or equalizing bar, with one of the lifting cables, attached **independently** at each extremity. The four lifting cables, after being thus attached, pass over a wrought iron girdle at the top of the car. Each cable carries an equal strain, and the breaking of any one cable puts the load on the other cables, which throws the rocker out of equilibrium, and forces the wedges on both sides instantly and immovably between the iron jaws of

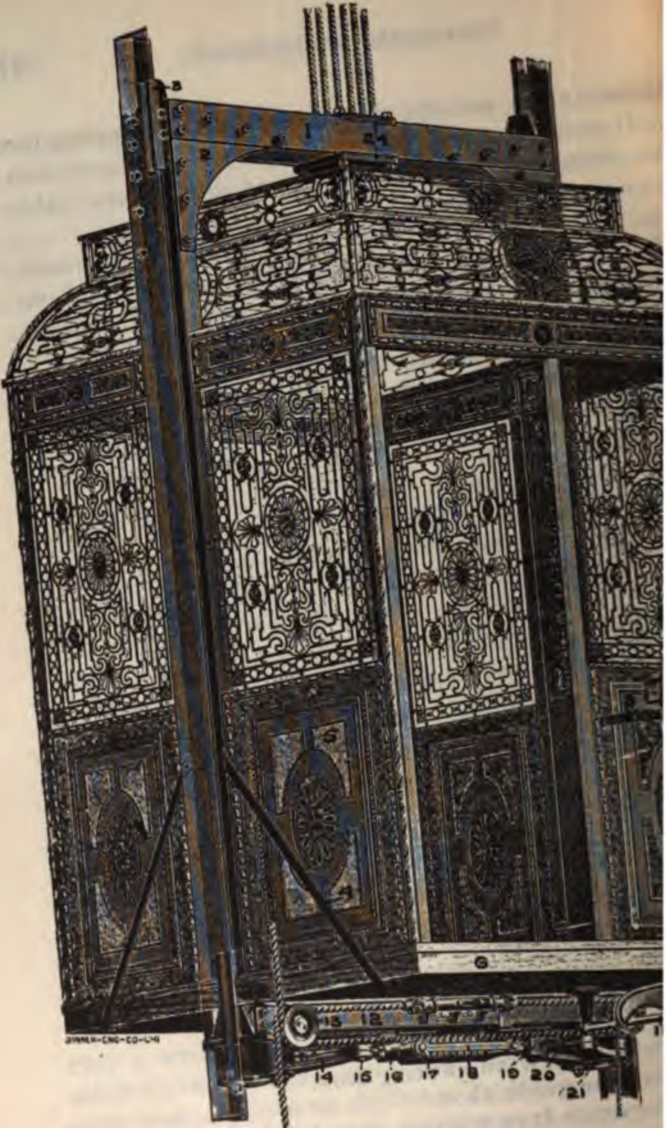
the safety plank and the side of the guides, **stopping the car.** It may be raised to any position by the unbroken cables, though it can **not** be lowered until a new cable is put on.

2. Any cable will always stretch before it breaks, which will throw the equalizing safety bar out of equilibrium and force the wedges on both sides into position. **No other safety device will give warning in advance.**

In Fig. 257 is shown an ordinary elevator cage or car, with its principal parts.

Parts.—

1. Cage beam.
2. Gusset plates.
3. Upper guide shoe.
4. Platform brace.
5. Car.
6. Cage platform.
7. Operating lever.
8. Operating lever quadrant.
9. Half moon.
10. Drop hanger.
11. Operating shaft.
12. Channel for safety plank.
13. Governor rope sheave on safety plank.
14. Friction jaws.
15. Pins for friction jaws.
16. Spring head (plain).
17. Safety spring.
18. Spring head connecting bars.
19. Coupling rod jaws.
20. Coupling links.
21. Friction jaw supporting link.
22. Bottom guide shoe.
23. Governor rope trigger, complete.
24. Upper and lower beam plates.



Elevator Car and Parts.

Fig. 257.

CARE OF HALE ELEVATORS, AS GIVEN BY THE MANUFACTURERS.

Keep the guide springs on the girdle above, and the afety-plank below the car adjusted so that the car will ot wabble, but not tight enough to bind against guides.

When cables are drawing alike, the equalizing bars n a passenger elevator should be horizontal, and the et screws free from contact with the finger shaft, but djusted so that one of them will come in contact with he finger shaft when the equalizing bar is tipped a cerain amount either way.

If the safety wedges should be thrown in, or rattle, when descending, the cause would be from the stretching r breaking of one of the cables, the action of the govrnor, or from weakness of either the spring on the finer shaft, safety-wedge or gummy guides.

In the first case, if occasioned by the cable stretchg, the cable should be examined thoroughly, and if it hows weakness, a new one put on, otherwise it can be hortened up, as stated above.

In the second case, the car had probably attained ccessive speed, and the governor simply performed its roper function.

In the third case, new springs should be put on, and e guides kept clean, for it often happens that the guides e so dirty that the springs cannot well prevent the edges catching.

All the safeties should be kept clean and in good rder, so that they will quickly respond when called upon perform their duty.

To loosen the wedges when thrown in, throw the alve for the car to ascend.

If the wedges are thrown in above the top landing,

remove the button on the hand cable, and run the car up until the piston strikes the bottom of the cylinder. If this is not sufficient to loosen the wedges, the car will have to be raised by a tackle.

Keep all nuts properly tightened.

If traveling or auxiliary sheave bushing is worn so that sheave binds, or the bushing is nearly worn through, turn it half round, and thus obtain a new bearing. If it has been once turned, put in a new bushing.

See that the piston rods draw alike. If they do not, it can be discerned by trying to turn the rods with the hand, or by a groaning noise in the cylinder. However, this groaning may also be caused by the packing being worn out, in which case the car would not stand stationary.

See that all supports remain secure, and in good condition.

If car settles, the most probable cause is that the valve or piston needs repacking. If packing is all right, then the air valve in the piston does not properly seat.

If the car springs up and down when stopping, there is air in the cylinder. When there is not much air, it can often be let out by opening the air cock and running a few trips, but when there is considerable air, run the car to near the bottom, placing a block underneath for it to rest upon, then place the valve for the car to descend. While in this position open the air cock and allow the air to escape. This may have to be repeated several times before the air is all removed.

Keep the cylinder and connections protected from frost. Where exposed, the easiest way to protect the cylinder is by an air-tight box, open at the bottom, at which point keep a gas jet burning during cold weather.

here there is steam in the building, run a coil near the linder.

Keep stop buttons on hand cable properly adjusted, that the car will stop at a few inches beyond either nding, before the piston strikes the head of the cylin-er.

Regulate the speed desired for the car by adjusting he back stop buttons, so that the valve can only be pened either way sufficiently to give this speed.

Occasionally try the governor to see that it works roperly.

Keep the machinery clean and in good order.

Cables and How to Care for Them.—Wire and hemp opes of same strength are equally pliable. Experience as demonstrated that the wear of wire cables increases ith the speed. Hoisting ropes are manufactured with emp centers to make them more pliable. Durability is ereby increased where short bending occurs. All twist-g and kinking of wire rope should be avoided. Wire pe should be run off by rolling a coil over the ground ce a wheel. In no case should galvanized rope be used r hoisting purposes. The coating of zinc wears off very ickly and corrosion proceeds with great rapidity. oisting cables should not be spliced under any circum-ances. All fastenings at the ends of rope should be ade very carefully, using only the best babbitt. All evises and clips should fit the rope perfectly. Metal stenings, where babbitt is used, should be warmed be-ore pouring, to prevent chilling.

Examine wire ropes frequently for broken wires. Wire hoisting ropes should be condemned when the wires (not strands) commence cracking

Keep the tension on all cables alike. Adjust with raw-bars and turnbuckles provided.

Lubrication of Worm Gearing.—Oils with a body, such as cylinder and castor oils, are best suited to the purpose. A composition of two parts castor to one part cylinder oil of very best quality, makes a desirable lubricant, for the following reasons: Cylinder oil being heavy with ample body, on becoming warm runs freely to the point of contact between the worm and gear and lubricates readily. On the other hand castor oil when cool or only slightly warm retains its body and makes an excellent lubricant. Upon becoming heated castor oil thickens, thus rendering it objectionable. By the combination efficient lubrication is obtained at all temperatures.

Lubrication of Cables.—A good compound for preservation and lubrication of cables is composed of the following: Cylinder oil, graphite, tallow and vegetable tar, heated and thoroughly mixed. Apply with a piece of sheepskin with wool inside.

To prevent wire rope from rusting apply raw linseed oil.

Lubrication of Guides.—Steel guides should be greased with good cylinder oil. Grease wood strips with No. 3 Albany grease or lard oil. Clean guides twice a month to prevent gumming.

Lubrication of Overhead Sheave Boxes.—In summer use a heavy grease. In winter add cylinder oil as required.

Leather Cup Packings for Valves.—Leather for cups should be of the best quality, of an even thickness, free from blemish, and treated with a water-proof dressing. The cups should be of sufficient stiffness to be self-sustaining when passing over perforated valve lining. When ordering cups, the pressure of water carried should be specified, as the stiff cups intended for hig

pressure would not set out against the valve lining when low pressure is used.

Water.—Water for use in hydraulic elevators should be perfectly clear and free from sediment. A strainer should be placed on the supply pipe and water changed every three months, and the system washed and flushed.

Closing Down Elevators.—If an elevator is to be shut down for an indefinite period, run the car to the bottom, and drain off the water from all parts of the machine, otherwise a freeze is likely to burst some part of the machinery. If the machine is of horizontal type, grease the cylinder with a heavy grease; if vertical, the rods should be greased. Oil cables with raw linseed oil.

Lubrication for Hydraulic Elevators.—The most effectual method of lubricating the internal parts of hydraulic elevator plants where pump and tanks are used, is to carry the exhaust steam drips from the foot of the pump exhaust pipe to the discharge tank, thus saving the distilled water and cylinder oil. This system is invaluable when water holding in solution minerals is used, as these minerals greatly increase corrosion.

Horizontal machines operated by city pressure are best lubricated with a heavy grease applied either mechanically or by means of a piece of waste on the end of a pole. The former method serves as a constant lubricator, while in the latter case greasing is often neglected, and in consequence packing lasts but a short time.

Useful Information.—To find leaks in elevator pressure tanks in which air is confined, paint around the rivet heads with a solution of soap and the leak will be found wherever a bubble or suds appear.

To ascertain the number of gallons in cylinders and round tanks, multiply the square of the diameter in

inches by the height in inches and the product by .0034 = gallons.

Weight of round iron: Multiply the diameter by 4, square the product and divide by 6 = the weight in pounds per foot.

To find the weight of a casting from the weight of a pine pattern, multiply 1 pound of pattern by 16.7 for cast iron and by 19 for brass. Ordinary gray iron castings = about 4 square inches to the pound.

Horse Power of Belting.—To ascertain transmitting power, multiply diameter of driving pulley in inches by its number of revolutions per minute and this product by width of belt in inches; divide this product by 3,300 for single leather, four-ply rubber or four-ply cotton belting—or by 2,100 for double leather, six-ply rubber or six-ply cotton belting, and the quotient will be the number of horse power that can be safely transmitted.

Belts and How to Care for Them.—The work required of an elevator belt is the most severe and we might say extraordinary character, running as it does over a large to a small pulley and beneath an idler, so situated as to give the small pulley as much belt surface as possible. The belt runs forward and backward as the cage ascends and descends, thereby causing a certain amount of slip. It is imperative that a belt performing such service should be of the very best quality. The following are the specifications:

The stock should be strictly pure oak tanned, cut in such a manner that the center of the hide will form the center of the belt. Each piece should have all stretch thoroughly removed. The belt should be short lap, none of the pieces to exceed 4 feet 2 inches in length, including the laps. Lock lap should be made which makes a perfect splice. Under no circumstances should

straight lap be used. The cement should be of the ery best quality and pliable to such an extent that it ill allow for the short turn taken by the belt passing nder the idler and around the small pulley. As a pre-aution against laps coming apart from accident or other ause, belts should be riveted, as the rivets will hold lap ogether until defect may be seen and remedied.

Owing to the high speed, laced belts should never be used, as the laces are sure to be cut by running over the small pulleys.

Castor oil makes a very reliable dressing for belts. It renders them pliable, thus improving the adhesive qualities.

Electric Elevators.—This type of elevators are made either (1) indirect-connected, or (2) direct-connected.

Indirect-Connected.—In this arrangement, the elec-tric motor is simply used for driving the **line-shafting** of an ordinary belt elevator.

Direct-Connected.—In this arrangement is elimi-ated the counter-shaft and the tight and loose pulley, nd the substitution therefor of a belt connecting the otor **directly** with the machine.

In the modern elevator the belt is also eliminated, d the motor is coupled directly to the **shaft** of the ele-tor machine. Such a machine is shown in Fig. 258.

Motors.—As the motor must start under load, it ust therefore get up speed rapidly, though gradually.

When it is relied upon the motor **alone** to do this, is then generally constructed of the compound wound pe, the series coil serving to give the torque at start-g, and the shunt coil **steadying** the field. When the otor is up to speed, the series coils are generally cut t, leaving the motor to be run as a simple shunt wound otor.

Where the operation of the motor is **not** relied upon alone, then controlling devices are used, which are hereinafter described.

Transmitting Devices.—Such devices between the motor and car consist of the ordinary worm gearing, drum, and rope.

Controlling Devices.—The power control consists of **breaking** the current, and the **reversing** of the motor. While a simple snap switch is all that is necessary to break the current, to **reverse** the travel of the car, i. e., the rotation of the motor, a reversing switch or pole charger is needed.

In practical operation of elevators, the complete apparatus necessary to control the electric motor is called a **controller.**

Counter-Balancing.—Direct connected electric elevators of the drum type are always over-balanced.

Electric Elevator Engines.—In Fig. 258 is shown the Otis Electric Elevator Engine with alternating current motor, for either passenger or freight service. These engines are designed for operation on two-phase or three-phase circuits of any commercial voltage and frequency, and can be provided with either electrical or mechanical control. The engine shown is arranged for mechanical control.

Systems of Control.—There are two systems of control for electric elevators—the **electrical** and the **mechanical.** In the former, the elevator is controlled by a small switch within the car, operating pilot circuits which open and close the main line and reversing switches. On starting, there is considerable resistance within the armature circuit, and as the motor accelerates this resistance is automatically cut out step by step by electrically operated switches. By this means, the current is abso-

The Otis Electric Elevator Machine.
Fig. 258.

lutely prevented from increasing above the amount for which the motor is designed and a gentle start, proportionate to load, is secured.

The **mechanical** system of control differs from that just described in that the line switch is opened, closed, and reversed through the medium of a lever or a handwheel within the car, by purely mechanical means. Closing the switch admits starting current only to the motor and thereafter the control proceeds in the manner already described in the respect that the starting resistance is cut out from the armature circuit by automatic switches step by step as the motor accelerates, the same protection of the motor against heavy currents being thereby afforded.

DIRECTIONS FOR THE CARE AND OPERATION OF THE CRANE OR OTIS ELECTRIC ELEVATORS, AS GIVEN BY THE MANUFACTURERS.

Warning.—Whenever the attendant wishes to handle the machine to clean, adjust, repair or oil it, he should see that the current is shut off at the switch and thus prevent all possibility of accident.

Cleaning.—Keep the entire machine clean.

Clean the commutator and other contacts and brushes carefully with a cloth and keep them free from grease and dirt.

If the face of the rheostat on which the rheostat arm brushes work becomes burnt, clean with a piece of fine sandpaper (No. 0), or if necessary use a fine file.

Keep all contacts smooth.

Try the rheostat arm when cleaning to be sure that it moves freely off contacts.

Oiling.—Oil the drum shaft bearings with good heavy oil.

Oil the worm and gear by filling the chamber around them with a mixture of two parts of good castor oil and one part good cylinder oil. Keep this chamber filled to the top of worm or mark on gauge glass, adding a little each day as it is used. The end thrust bearings of the machine are automatically oiled from this chamber. This should be drawn off every two or three months and replaced by fresh oil.

Oil the motor bearings with dynamo oil. These are automatically oiled, but should occasionally be supplied with fresh oil. Lubricate the commutator, rheostat face, drum switch and contacts **very sparingly** with a cloth moistened with oil. Care should be taken not to apply too much oil to these parts.

Keep the oil dash pot, if any, sufficiently filled with oil to allow the rheostat arm to move quickly on to the first contact and to retard its movement beyond this contact. The best oil for this purpose is fish oil or some thin oil that is not readily affected by changes in temperature.

If an air dash pot is used keep it slightly oiled so as to keep the packing soft.

Keep all parts of the elevator, including sheaves, guides, cables, etc., clean and well oiled.

Operating.—Before switching the current on to the machine, be sure that the operating lever is in its central position.

To ascend, draw the lever the full throw to the **up.**

To descend, draw the lever the full throw to the **down.**

To run at slow speed, bring the lever toward the center according to the speed desired.

To stop, bring lever to slow speed when within four feet of landing, and to its central position when close to it. In this way the operator can make accurate stops.

When starting (machines on which the solenoid is used) if the current is admitted to the motor too rapidly, thereby starting the car with a jerk or momentarily dimming the lights on the circuit, check the speed with which the resistance is cut out of the armature circuit by slightly easing off the weight which acts in opposition to the core of the small solenoid. This solenoid controls a valve in the dash pot and thereby regulates its speed in proportion to the current passing.

If a governor starter is used and the current is admitted too rapidly tighten the governor spring on the armature shaft, or close the vent in air dash pot.

If the car refuses to ascend with a heavy load, immediately throw the lever to the center and reduce the load, as in all probability it is greater than the capacity of the elevator.

If it refuses to ascend with a light load, throw the lever to the center and have the fusible strip examined.

If in descending the car should stop, throw the lever to the center, and examine safeties, fusible strip and machine, and before starting be sure that the cables have not jumped from their right grooves.

If the car refuses to move in either direction throw the lever on the center and have the fusible strips examined. Never leave the car without throwing the lever to the center.

If the car should be stalled between floors, it can be either raised or lowered by raising the brake and running it by turning the brake wheel by hand. Such a stoppage might be caused by the current being shut off at the station, undue friction in the machine, too heavy a

ıad, fuses burnt out, or a bad contact of the switches, inding posts or electrical connections.

If the car by any derangement of cables or switch annot be stopped, let it make its full trip, as the automatic stop will take care of it at either end of the travel.

The bearings should be examined occasionally to insure no heating and proper lubrication.

The attendant should inspect the machine often.

All brushes and switches should be sufficiently tight) give a good contact, but no tighter.

None of the brushes should spark when in their norıal position.

When the brushes become burnt dress with sandıper or a file, or if necessary replace with new ones.

If brushes spark, dress with sandpaper or file to a ›od bearing, and if necessary set up springs, but do ›t make the tension such as to interfere with their ready ovement.

Adjust commutator brushes gradually for least ›arking. These should be close to the central position.

Contacts and brushes should be kept clean and mooth, and lubricated sparingly.

While replacing a fusible strip, be sure that main witch is open, and be careful not to touch the other wire rith your tool or otherwise, as such contact would be langerous.

Never put in a larger fuse than the one burnt.

Inspect the worm and worm wheel occasionally hrough hand-hole in casing to see that they are well lubricated and that no grit gets into the oil. They should show no wear.

The stuffing-box on the worm shaft should be only tight enough to keep the oil from leaking out of the worm chamber.

Be sure that all parts are properly lubricated, and that none of the bearings heat.

To make sure that the car and machinery run freely, lift brake lever and then rotate worm shaft by pulling on the brake wheel. The empty car should ascend without any exertion.

Keep operating cables properly adjusted.

Open main switch when the elevator is not in service.

The Marine Electric Elevator.—The construction of this elevator, as shown in Fig. 259, possesses many excellent points; therefore, the specifications for this machine are given below, not only to show the characteristic features, but as a most instructive way to present to the student the requirements in the construction of a modern electric elevator.

Construction.—Bed Plate.—One solid iron casting to keep all bearings in perfect alignment.

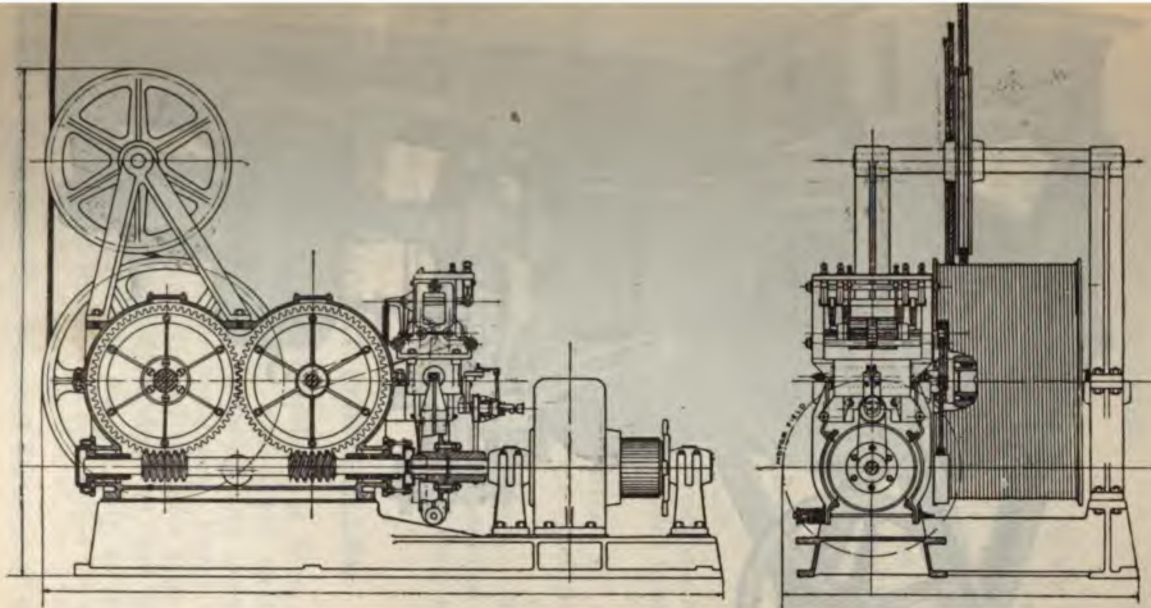
Motor.—The motor is of the slow speed multipolar type, compound wound, having a strong series field to promote easy starting, and will stand temporary excessive overload without flashing at the brushes or injurious heating.

The armature is wound with formed coils and perfectly ventilated, balanced both electrically and mechanically and runs in self-aligning and self-oiling bearings.

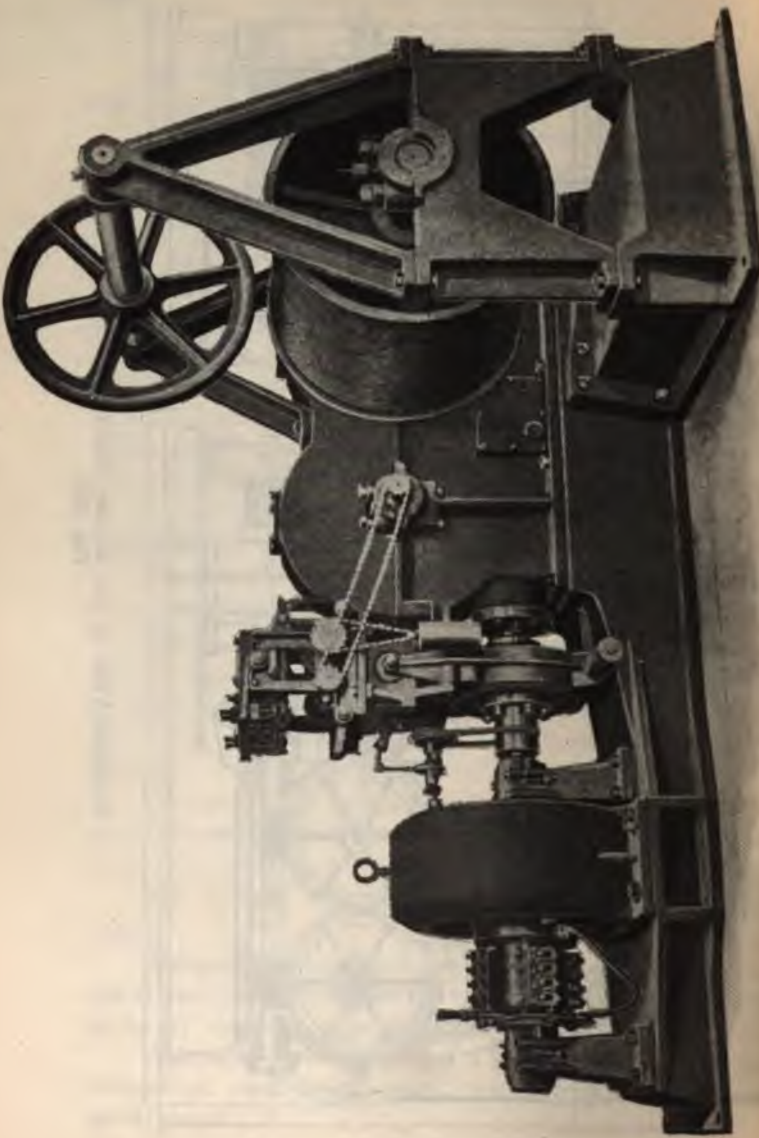
The brushes are carbon and independently adjustable.

Gears.—The gears, of the best bronze, are cut on a spiral gear cutter, the teeth are the helical form that mesh perfectly and give the smoothest possible motion.

Worms.—The worms are a part of the high carbon hammered steel worm shaft, and are hobbed into the spiral gears.



Sectional View of the Marine Electric Elevator.
Fig. 259.



Drum.—The drum is secured and driven by six (6) turned coupling bolts fitted into reamed holes in a flange forged on to the drum shaft. The gear spider is secured in the same way to the same shaft.

Brake.—The brake magnet, to which the brake levers are pivoted, is bolted to the gear case. The shoes are made of cast iron lined with cork formed to fit the pulley. The pressure is applied by a spring and released by energizing the magnet.

Limit.—The limit is mounted on the brake magnet and driven by a nickel steel sprocket chain, of 2,500 pounds breaking strength, from the gear shaft.

Slack Cable Device.—The slack cable device is a balanced bar under the drum, bringing the controller to stop upon the slacking of the ropes.

Governor.—A centrifugal governor, driven by the worm shaft, applies the brake whenever the normal speed is exceeded.

Lubrication.—All bearings are self-oiling. The worms run entirely submerged, and the oil, paddled up by the gears, flows through the gear shaft bearing and back into the gear case.

THE MARINE MAGNET CONTROLLER.

Contruction.—This type of controller has been designed for use in connection with high speed electric drum machines, where rapid acceleration and general hard service is demanded of the apparatus. Every detail of the design and manufacture of this new type of controller has been most carefully worked out, and only such parts have been utilized in its assembly as long service has demonstrated them to be best suited for the service demanded.

Essential Features.—The essential features of this

controller are the reversing switches shown on the low panel, and the six accelerating magnets on the upp panel. The Series Field Magnet between the reversin switches operates automatically to cut out the series co of the motor, after the machine has started. The sma relay controls the circuit to the accelerating magnets a the machine brake coil. See Fig. 261-(1).

Reversing Switches.—The reversing switches a operated by the cores of the magnets, against gravit to close the circuit to the motor. Rapid and positi action is assured in this form of electro-mechani switch with failure to open unknown. The contacts a of copper and carbon, of large capacity, independen adjustable and having long life.

Accelerating Magnets.—The six accelerating ma nets control the starting resistance in the main mo circuit, and are so connected that they must operate succession to short circuit the sections of the resistan which they control.

The accelerating magnets are made up of the stan ard parts used on the reversing switches and opera against gravity, to cut out the starting resistance.

Starting Resistance.—The starting resistance co sists of a bank standard cast iron grids, mounted on slate base at the rear of the controller. This type "current diverter" is practically indestructible, and is t standard for all heavy electrical duty of this character.

Car Switch.—The car switch is of the "automa stop lever" type, especially designed for use in conn tion with the magnet controller. The lever is autom ically locked on the "stop" position and cannot be mov unless the latch under the handle is first raised. T contacts are easily renewed if required.

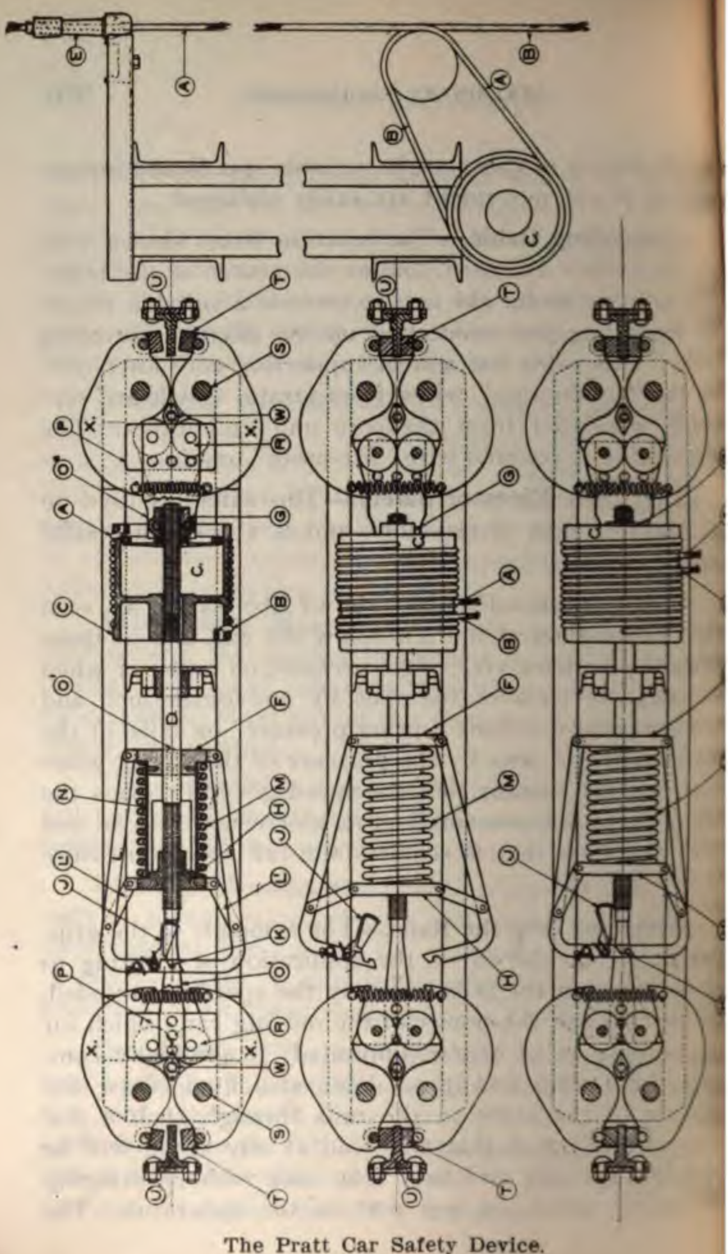
By means of this switch, variable speeds and instant eversal of car movement are easily obtained.

Controlling Cable.—The junction boxes shown with he car switch are used, one at the center of the hoistway and one under the car, to provide a suitable means or supporting and connecting up the electric controlling able. This cable has a steel supporting core for relieving the "conducting" wires from strain, which are separately insulated from the core and each other. The whole cable is covered with "fire-proof" braid.

The Pratt Elevator Safety.—This safety is used on the Marine make of elevators, and is a most successful device.

Construction.—Fig. 260 shows the safety as seen when looking up at it from below the car, and in three different positions, viz.: "No pressure on rails," or when the jaws are clear of the rails by one-fourth inch and the car is ready to run; "spring pressure" on rails, or the first grip of the jaws by the pressure of the spring when unlatched the instant that the speed governor grips the rope; "maximum pressure" on rails or when the load and speed are such that it requires the full spring pressure to stop the car.

Device to Grip the Rails.—The principle of the gripping device on the car is the application of a spring to set the jaws on the rails instantly the speed is exceeded, and then to use the power of the moving car (which for this purpose is, of course, unlimited) to gradually compress this spring and in so doing steadily increase the pressure of the jaws on the rails through such a distance of car travel that any load at any speed will be brought to a safe and easy stop, and without bringing any undue strain on any part of the apparatus. The



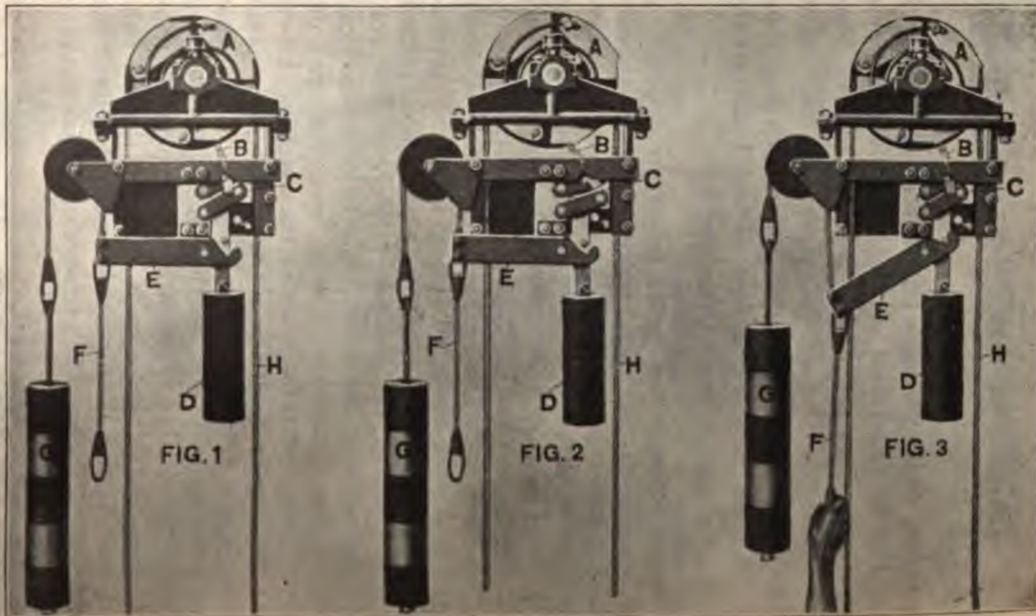
The Pratt Car Safety Device.
Fig. 260.

particular mechanism by which this is accomplished is shown in Fig. 260.

Operation of Governor.—Fig. 261 shows spring F closed, either by the travel of the car under maximum load and speed, or by pulling the governor rope by hand to relock the toggles before the screw C is revolved in the reverse direction by hand pull on the governor rope, in order to push back the wedges H and J and restore the safety to the position "no pressure on rails."

Governor Rope.—This figure has a sketch showing the rope connections between the governor and the car, in which B is the rope passing over the governor sheave T, leading down through the driving grip Y on the car, under the idler sheave and around the drum A where this end of it is anchored at B, as shown in the sectional view. The other end of this same piece of rope is shown in the sectional view anchored at S on the drum A, passing over an idler sheave and down to the tension sheave U at the bottom of the hoistway. Here is one continuous rope, without the several splices or connections common to other systems and being wound around the drum A in both directions enables the safety to be released by the engineer outside of the car from any point in the hoistway. It will be seen from this sketch that the governor rope is driven by the car by grip Y until the adjusted speed is exceeded, when the governor grips the rope, stops it, driving grip Y releases, the car continues to travel, and the drum A to revolve until the car is stopped by the gradual pressure of the jaws on the rails.

The Pratt Car Safety Device.—The action of the safety device on the car (the success of which depends



The Marine Governor.

in the first place upon a reliable governor as above described) is as follows:

Construction.—Drum A is keyed on the right hand thread of shaft C. Shaft C has a right hand thread on the right hand end and a left hand thread on the left hand end. At the first advance of the left hand end of the screw through the nut E, it pushes the push bar P and trips the latch Q, unlocks the toggles RR and allows the spring F to extend. When the spring F extends, it carries nut E, screw C and wedges H to the left, and spring head G and wedges J to the right. Wedges H and J, being thus drawn together, separate each pair of rolls K, thus moving the two pairs of levers L about their pivots M and brings the jaws N against the steel guide rails O. This is the position marked "Spring Pressure" in Fig. No. 260, and only brings the jaws on the rails with sufficient pressure to check and not to stop the car. Further travel of the car continues to revolve screw C, compressing spring F, and increasing the pressure of the jaws on the rails until the car is brought to an easy stop.

Governor Grip.—The grip on this governor is so accurately in line with and so near to the sheave that the rope cannot rub on and wear it. It is also a long grooved jaw that will not injure the rope.

The Marine Governor.—Fig. 261 shows the speed governor with side plate removed to show the rope grip. In this governor four freely pivoted weights, held by a spiral spring against centrifugal force, fly out, at whatever speed the tension of the spring is adjusted for, and a lug on the weight approaching the latch, strikes this latch and releases the latch pin and allows the weight to fall and bring the toggle grip against the rope. For safeties that are required to stop the car going either up

tions for this governor
with a safety device o
ernor (located overhea
mal speed the centrifu
stops the safety rope,
safety rope brings the
tact with the rails in r
travel, and whereby th
a distance of six feet s
the jaws on the rails u
and easy stop.

The Jones Control
signed for use with ho
car speed is desired and
up to 25 horse power c

Fixed Speeds.—Th
having special shunt fie
speeds.

Special Features.—
of controller are the re
netic reversing switche

Resistance Regulat

position by the lock lever located at the left of eostat, under the small relay.

utomatic Locking.—At the same instant that the arm is locked in this full speed position, the cur- automatically cut off from the solenoid coil op- the regulator, thereby preventing heating of the operation.

avity Return.—In stopping, the plunger of the magnet falls on the lock lever and releases the arm, allowing it to return by gravity to the nor- top" position.

versing Switches.—The reversing switches are of rd type, closing against gravity by the action of re of the operating magnets. The contacts are **arge** for the duty required and consist of inde- tly adjustable carbon and copper pieces always ting a flat surface to the contact plates attached magnet plungers.

rge Carrying Capacity.—This design insures the um carrying capacity and the minimum wear on ts.

nnot Start Too Suddenly.—The operating coils of ersing switches are so connected that the **switches be closed until the brush arm has returned to the starting position,** thereby introducing all of the resistance in the armature circuit and preventing id starting of the elevator.

possible to Overload Motor.—A desirable feature controller is an adjustment which is provided to t, automatically, the starting of the motor when contains a load in excess of the usual maximum y. This device prevents overloading of the motor its safe limit.

SPECIFICATIONS FOR THE W. A. MILLER DIRECT CONNECTED ELECTRIC ELEVATORS.

Electric Current Controllers and Safety Devices.—The electric motors will be run in either direction to run the elevators up or down as desired by the electric reversing switch, which is operated by either the operating cable or lever from the platform or landings. By working the operating cable or lever the reversing switch is closed in the proper way to run the motor in the direction to send the elevator, either up or down, as desired. As soon as the electric reversing switch is closed the electric current controller will allow the electric current to enter the motor with a gradually increasing force so as to quickly and smoothly start the elevators. This current controller will start the elevator with a smooth motion, whether the operator starts the elevator quickly or slowly.

Slack Cable Stop.—There will be devices on the hoisting machine which will automatically stop the elevator by cutting out the current and applying the safety brake in case the hoisting cables should get slack or break, and thus prevent accident and the breaking and entangling of cables.

Machine Stops.—On the hoisting machine will be a device which will automatically stop the elevator by cutting out the current and applying the safety brake when the elevator reaches either top or bottom landing.

Safety Brake.—On the hoisting machine will be a safety brake which will gradually and smoothly stop the platform and elevator when the current has been cut out.

Operating Cable Stops.—On the operating cable will be a device which will automatically stop the elevator by cutting out the current and applying the safety brake when the platform reaches either the top or bottom landing, if the operator should neglect to stop the elevator

PECIFICATIONS FOR A MOLINE DIRECT-CONNECTED ELECTRIC FREIGHT ELEVATOR.

Motor.—The motor will be constructed especially for levator service. It will be compound wound, and will e provided with "End On" carbon brushes, and will ot spark. The motor is especially designed for obtaining a very quick start with a low consumption of current. The motor will be controlled by our automatic controller. The arrangement of the controller is such as to ecure a gradual and easy start and stop of the elevator ar, independent of the skill of the operator.

Hoisting Machine.—The hoisting machine will be made from our new and improved patterns, and will be ecurely fastened to overhead deck, furnished and placed r you.

This machine will be completed with solid forged teel screw on a steel shaft, and phosphor bronze worm wheel, and both worm and worm wheel will be accurately cut by special machinery to a standard gauge, and rotected by an oil-tight chamber so that the worm will e surrounded with oil at all times.

The end thrust on worm shaft will be furnished with ur improved anti-friction bearings, which make a large eduction in friction, and is guaranteed to run without eating. The bearings in this machine will be lined with the best quality copper hardened babbitt metal. It will have an automatic brake, limitation top and bottom top, and slack cable stop.

The winding drum will be made extra heavy, of the est grade of cast iron, of suitable diameter, turned and grooved to receive ¾-inch diameter cable.

All parts will be mounted on heavy cast iron bed plate, so that there can be no heating of bearings from parts getting out of line.

STANDARD HOISTING ROPE WITH 19 WIRES TO THE STRAND

IRON.

Trade No.	Diameter.	Circumference in inches.	Weight per foot in lbs. of rope with hemp center.	Breaking strain in tons of 2000 lbs.	Proper working load in tons of 2000 lbs.	Circumference of new Manilla rope of equal strength.	Minimum size of drum or sheave in feet.
1	$2\frac{1}{4}$	$6\frac{3}{4}$	8.00	74	15	14	13
2	2	6	6.30	65	13	13	12
3	$1\frac{3}{4}$	$5\frac{1}{2}$	5.25	54	11	12	10
4	$1\frac{5}{8}$	5	4.10	44	9	11	$8\frac{1}{2}$
5	$1\frac{1}{2}$	$4\frac{3}{4}$	3.65	39	8	10	$7\frac{1}{2}$
$5\frac{1}{2}$	$1\frac{3}{8}$	$4\frac{3}{8}$	3.00	33	$6\frac{1}{2}$	$9\frac{1}{2}$	7
6	$1\frac{1}{4}$	4	2.50	27	$5\frac{1}{2}$	$8\frac{1}{2}$	$6\frac{1}{2}$
7	$1\frac{1}{8}$	$3\frac{1}{2}$	2.00	20	4	$7\frac{1}{2}$	6
8	1	$3\frac{1}{8}$	1.58	16	3	$6\frac{1}{2}$	$5\frac{1}{4}$
9	$\frac{7}{8}$	$2\frac{3}{4}$	1.20	11.50	$2\frac{1}{2}$	$5\frac{1}{2}$	$4\frac{1}{2}$
10	$\frac{3}{4}$	$2\frac{1}{4}$	0.88	8.64	$1\frac{3}{4}$	$4\frac{3}{4}$	4
$10\frac{1}{4}$	$\frac{5}{8}$	2	0.66	5.13	$1\frac{1}{4}$	$3\frac{3}{4}$	$3\frac{1}{2}$
$10\frac{1}{2}$	$\frac{9}{16}$	$1\frac{5}{8}$	0.44	4.27	$\frac{3}{4}$	$3\frac{1}{2}$	$2\frac{3}{4}$
$10\frac{3}{4}$	$\frac{1}{2}$	$1\frac{1}{2}$	0.35	3.48	$\frac{1}{2}$	3	$2\frac{1}{4}$
10a	$\frac{7}{16}$	$1\frac{3}{8}$	0.29	3.00	$\frac{3}{8}$	$2\frac{3}{4}$	2
$10\frac{7}{8}$	$\frac{3}{8}$	$1\frac{1}{4}$	0.26	2.50	$\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{1}{2}$

:.—Wainscoting of iron on two sides, 5 feet he cage, or platform, will be made of channel ne and of side post pattern. It will be 12 feet and 14 feet from front to back. It will be ar- › travel from landing at basement to landing at floor, a distance of 92 feet 2 inches.

es.—The elevator will be equipped with six ¾- ıeter wire cables of the best Swedish iron. The rength of hoisting cables is about 18,000 pounds

:ating Device.—The elevator will be operated by pull tiller cable of ½-inch diameter for starting ping, which is so arranged as to give the oper- ect control of the apparatus.

ves.—The main hoisting and counterbalancing will be of as large diameter as the hatchway ıtion of machine will admit. They will be in the lathe to fit the cables, and be provided vy steel shafts, which run in heavy boxes, truly ith suitable means for oiling. All these sheaves ıpported by heavy yellow pine beams and where will be supported on the guide posts.

le Posts.—The guide posts will be made of pine, d built, accurately planed, and will be securely to each floor in the building in a substantial Hard maple guides fastened to these guide l form a guide-way for the cage, which makes a and durable construction. The weight guides ıade of hardwood and will be securely fastened vay to each floor of the building.

SAFETY APPLIANCES.

›matic Top and Bottom Stop.—First. The auto- ›p is placed on the operating cable, which stops

Head in Feet.	Pounds pressure per square inch.	DIAMETERS OF ORIFICES IN INCHES AND FRACTIONS OF AN INCH.									
		¼ Inch.	⅜ Inch.	½ Inch.	⅝ Inch.	¾ Inch.	1 Inch.	1¼ Inch.	1½ Inch.	1¾ Inch.	2 Inch.
20	8.66	300	720	1260	1920	2760	4920	7380	11100	15120	19740
40	17.32	450	960	1800	2760	3960	6720	10920	15720	21360	27960
60	25.99	540	1200	2160	3480	4800	8580	13380	19200	26220	34260
80	34.65	620	1380	2460	3840	5580	9840	15480	22260	30300	39540
100	43.31	690	1560	2760	4320	6240	11040	17280	24900	33900	44280
120	51.98	780	1680	3000	4740	6840	12120	18960	27240	37440	48480
140	60.64	816	1860	3300	5100	7320	13020	20160	29460	39080	52320
150	64.97	840	1920	3420	5280	7620	13560	21180	30480	41460	54120
175	75.80	900	2040	3660	5700	8220	14640	22800	32880	44940	58560
200	86.63	960	2220	3900	6120	8760	15600	25020	35880	47880	62580
235	101.79	1080	2460	4320	8280	11160	17100	26760	38520	52260	68460

Gallons Discharged per Hour Through Various Sized Orifices Under Stated Pressure.
Table No. 24.

e cage at the upper and at the lower landings, inde-
:ndently of the operator.

Automatic Limitation Stop.—Second. The auto-
atic limitation stop, which stops the cage at the lower
ıd upper landings in case the regular operating cable
: lever device should get disarranged. Its action not
ıly prevents an accident or damage to the cage that
ıight result thereby, but it also protects the lifting cables
om injury arising from overwinding.

Safety Brake.—Third. The safety brake is controlled
y the operating cable and automatic stop, and is applied
henever the current is shut off, holding the cage at any
:sired point.

Slack Cable Stop.—Fourth. The slack cable stop,
hich stops the machine and thus prevents the unwind-
g of the cables should the cage meet any obstruction
descending.

Safety Grip.—Fifth. The platform will be fitted
ith bottom eccentric steel safety grips, which are in-
nded to grip the guides and prevent the fall of the plat-
rm in case of the breaking or slacking of the cables.

Elevator will be equipped with safety speed gover-
)r.

Capacity.—The elevator will have a lifting capacity
5,000 pounds, exclusive of weight of cage, at a speed
90 feet per minute.

Preparing the Building.—You are to prepare the
atchways, and to prepare suitable room for the power;
) do all cutting of walls; to furnish proper supports in
lace for guide posts and sheave beams, and do all paint-
ıg except machinery. Should the roof be too low to
llow the cage to travel to top landing, you are to make
uch changes in the roof as may be necessary to admit
he sheaves and beams, and to properly protect same.

HORSE POWER TRANSMITTED BY HEAVY DOUBLE BELT.

Width of Belt in Ins.	Velocity in Feet Per Minute.										
	800	1200	1600	2000	2400	3200	3600	4000	4400	4800	5600
	Horse Power Transmitted.										
2	4½	6¾	9	11¼	13½	18	20¼	22½	24¾	27	31½
4	9	13½	18	22½	27	36	40½	45	49½	54	63
6	13½	20¼	27	33¾	40½	54	60¾	67½	74¼	81	94½
8	18	27	36	45	54	72	81	90	99	108	126
10	22½	33¾	45	56¼	67½	90	101¼	112½	123¾	135	157½
12	27	40½	54	67½	81	108	121½	135	148½	162	189
14	31½	47¼	63	78¾	94½	126	141¾	157½	173¼	189	220½
16	36	54	72	90	108	144	162	180	198	216	252
18	40½	60¾	81	101¼	121½	162	182¼	202½	222¾	243	283½
20	45	67½	90	112½	135	180	202½	225	247½	270	315
24	54	81	108	135	162	216	243	270	297	324	378
30	67½	101¼	135	168¾	202⅜	270	303¾	337½	371¼	405	472½
36	81	121½	162	202½	243	324	364½	405	445½	486	567
40	90	135	180	225	270	360	405	450	495	540	630
44	99	148½	198	247½	297	396	445½	495	544½	594	693
48	108	162	216	270	324	432	486	540	594	648	756

These calculations are based on first-class belting, made from backs of Pure Oak Tanned Leather, run under ordinary conditions and on pulleys of fair and equal size.

When the driven pulley is smaller, the power transmitted will be as much less than the above as that part of the surface of the driven pulley, which is covered by the belt, is less than half its surface.

Table No. 25.

You are to bring the power wires into the building within six feet of the motor and connect the same to our motor switch. The basis of this contract is that the current shall be constant potential, with 500 volts pressure at the motor, and it is a part of your contract to apply the current to the motor, as above specified. It is also understood you are to be responsible for the safety of the machinery after being delivered at building.

Guarantee.—We hereby **guarantee** the machinery, and all parts of the elevator specified in this contract, to be of the quality and description named herein, and to do the service specified herein, and we agree to make good any repairs on the engine and machinery or any part of the edevator which may be made necessary by any defective material or workmanship within one year from the date of completion.

SPECIFICATIONS FOR AN ELLISON SCREW GEAR POWER FREIGHT ELEVATOR.

Description.—We propose to furnish and erect complete, in building No. .... of our latest improved and best make of Worm Gear Power Elevators, of 2,000 pounds capacity, arranged for freight service, to be operated by power furnished, and to travel from first floor to third floor, a distance of about 23 feet, at a speed of 40 feet a minute, according to the following detail specifications:

Machine.—The machine is fitted on iron frame to suspend from the ceiling.

Winding Drum.—The winding drum is cast iron, 32-inch diameter, smoothly turned and grooved to receive two hoisting cables.

Worm Wheel.—The worm wheel will be cast iron,

HORSE POWER OF IRON AND STEEL SHAFTS

FOR GIVEN DIAMETER AND SPEED

Diameters of Shaft in Inches	Revolutions per Minute									
	100	125	150	175	200	225	250	300	350	400
1¼	2.4	3.1	3.7	4.3	4.9	5.5	6.1	7.3	8.5	9.7
1½	4.3	5.3	6.4	7.4	8.5	9.5	10.5	12.7	14.8	16.9
1¾	6.7	8.4	10.1	11.7	13.4	15.1	16.7	20.1	23.4	26.8
2	10.0	12.5	15.0	17.5	20.0	22.5	25.0	30.0	35.0	40.0
2¼	14.3	17.8	21.4	24.9	28.5	32.1	35.6	42.7	49.8	57.0
2½	19.5	24.4	29.3	34.1	39.0	44.1	48.7	58.5	68.2	78.0
2¾	26.0	32.5	39.0	43.5	52.0	58.5	65.0	78.0	87.0	135.0
3	33.8	42.2	50.6	59.1	67.5	75.9	84.4	101.3	118.2	171.8
3¼	43.0	53.6	64.4	75.1	85.8	96:6	107.3	128.7	150.3	214.4
3½	53.6	67.0	79.4	93.8	107.2	120.1	134.0	158.8	187.6	214.4
3¾	65.9	82-4	97.9	115.4	121.8	148.3	164.8	195.7	230.7	243.6
4	80.0	100.0	120.0	140.0	160.0	180.0	200.0	240.0	280.0	320.0
4½	113.9	142.4	170.8	199.3	227.8	256.2	284.7	341.7	398.6	455.6
5	156.3	195.3	234.4	273.4	312.5	351.5	390.6	468.7	546.8	625.0
5½	207.9	260.0	311.9	363.9	415.9	459.9	520.0	623.9	727.9	830.0
6	270.0	337.5	405.0	472.5	540.0	607.5	675.0	810.0	945.0	1080.0
6½	343.3	429.0	514.9	600.7	686.5	772.4	858.0	1029.0	1201.0	1372.0
7	428.8	535.9	643.1	750.3	847.5	964.7	1071.9	1286.0	1500.0	1696:0
8	640.0	800.0	960.0	1120.0	1280.0	1440.0	1600.0	1920.0	2240.0	2560.0

Table No. 26.

6-inch diameter, 3-inch face, the cogs of which will be ut on the gear cutting machine.

Worm.—The worm will be cast steel, cut from the solid in engine lathe, 5½-inch diameter, 1½-inch pitch.

Worm Gear Case.—The worm gear case and barrel will be in one piece, with a tight stuffing-box; this forms an oil chamber, thereby having the gears always thoroughly lubricated.

Anti-Friction Ball Bearing.—The worm shaft is fit-ed with an anti-friction ball bearing to take the end hrust; this ball bearing runs in a separate oil chamber, o arranged as to greatly reduce the friction of the ma-hine and prevents heating. In case of accident this ball earing can be easily removed and repaired or replaced vith a new one.

Safety Brake.—The safety brake is so arranged as to e automatically applied whenever belts are on loose ulleys, and released when either belt is shifted on tight ulley. The safety brake will be so arranged that it can e adjusted to the wear and work by means of a set-screw and lock-nut, and can be adjusted as well when nachine is in motion as when at rest.

Automatic Stop.—The automatic stop forms part of the machine proper, and is so arranged as to stop it and apply the safety brake when the cage reaches either the top or bottom landings, independent of the starting and stopping cables. This prevents the winding drum from making more than the necessary revolutions to carry the cage to the bottom or top of lift.

Slack Cable Stop.—Our improved slack cable stop prevents the unwinding of the cables. Should the cage meet with any obstructions in its descent, then this stop will shift the belts, apply the safety brake, stop the cage at once, and prevent accidents that might occur.

Countershaft.—The countershaft will be of proper diameter and length, and provided with necessary hangers and pulleys, suitable size to run elevator proper speed.

Belting.—The driving belt from .... to countershaft will be endless, ... wide. The two elevator belts from countershaft to elevator pulleys ...... wide. All to be proper length. To be furnished by you.

Driving Pulley.—The driving pulley on line shaft will be .. diam. x .. face. To be furnished by you.

Guarantee.—We guarantee our machinery in every part to be free from defects of either material or workmanship, and equal to, if not superior, in strength, durability and light running, to any of its class made; and should any such defects appear within one year, we will repair or make same good free of cost to you.

Preparing Building.—You are to prepare or provide the necessary hatchways free of expense to us, as also any doors, gates or enclosures. If there is not sufficient height in upper story to permit of placing the sheaves under the roof, and allow cage to reach top floor, it will be necessary to place them above the roof, in which case you enclose or cover same. To avoid this, the top story should not be less than 12 or 14 feet high.

Pulleys.—The three pulleys will be cast iron, 18-inch diameter by 4½-inch face, and will be turned true and balanced. The loose pulleys will be provided with capacious oil chambers, bronze brushes, and a greatly improved self-oiling apparatus. By this combination we secure greater durability than by any other known method. The lifting pulley is of larger diameter than the loose pulleys, thus preventing unnecessary strain on the machine and belts when the winding drum is not in motion.

Cage.—The cage will be made of seasoned hardwood

timber, with all needed iron work and braces, and arranged for guide posts at sides of hatchways. The platform will be about 7x8 feet, or proper size to suit present hatchways in building.

Guide Posts.—The guide posts will be yellow pine, 6x6 solid, and on these will be securely fastened the guide strips on which the cage guides will run smoothly.

Counter Balance and Guides.—The counter balance weight will be cast iron, made in sections and detachable, and of sufficient weight to balance cage, leaving only weight enough to bring cage down when empty.

The weight guide strips will be white pine, $2\frac{1}{2}$x$3\frac{1}{2}$ inches, with a groove in one side to guide the weight.

Sheaves.—The overhead sheaves will be heavy cast iron of large diameter, smoothly turned in groove, and fitted with heavy steel shafts and babbitted boxes, and supported by suitable timbers.

Cables.—The cage will be supported by two $\frac{5}{8}$x19 Swede's iron wire cables for hoisting, each of which is capable of standing a strain of ...... tons. The starting and stopping arrangements will be operated by one $\frac{1}{2}$x19 Swede's iron wire cable.

The counter balance weight will be supported by one $\frac{5}{8}$x19 Swede's iron wire cable. All cables to be of best quality made.

Our elevators are provided with the following safety appliances:

Safety Pawls.—The safety pawls are attached to the cross beam of the cage, and are operated by a steel spring. In the event of the parting of the lifting cables, or if the cage meets with any obstructions in its descent, these engage with the uprights and securely lock the cage.

Stop Buttons.—The stop buttons are attached to the starting and stopping cables to stop the cage at the top and bottom landing, independent of the operator.

Magnet Controller.
Fig. 261-(1).

The Standard Plunger Elevator.
Fig. 261-(2).

THE STANDARD PLUNGER ELEVATOR OF NEW YORK.

Description.—In the **Plunger Elevator** the car is supported from beneath by a moving column or plunger of approximately the same length as the travel of the elevator. This plunger works in a cylinder sunk vertically in the ground directly under the car. The cylinder is closed at the bottom, and at the top provided with a stuffing box through which the plunger passes; also with an opening for the inlet and outlet of water. The space between the plunger and cylinder is filled with water which sustains and moves the plunger and with it the car up or down. The opening in the cylinder is connected through a pipe to a three-way valve so arranged that when in central position the opening in the cylinder is closed and the elevator at rest. When the valve is opened in one direction, water under pressure will enter the cylinder and force the plunger upward. If the valve is reversed the water in the cylinder is forced out by the weight of the car plunger, and the elevator will come down. This valve may be operated directly **by hand** through a rope running through the car, or controlled **hydraulically** by means of a pilot valve, which in turn is operated directly by the operator. The weight of the car plunger is usually counterbalanced, leaving only enough preponderance on the car side to make the elevator come **down** at the desired speed.

Construction.—The car frame is T steel, strongly bolted and braced, and provided with easy running shoes. The plunger is made of specially selected steel pipe finished to a uniform outside diameter and highly polished. The separate sections are joined together by extra heavy inside steel nipples. The cylinder is made of steel pipe joined together by outside coupling, making butt

joints. The bottom is welded together, and the top is provided with an extra heavy casting with opening for the water, and means for attaching the stuffing box. The well for the cylinder is bored by special machinery, and where necessary provided with a steel casing. The car and counterweight run on steel guides, and the connection between same are made of extra heavy iron or steel ropes of proper weight to compensate for the variable buoyancy of the plunger.

Merits.—The plunger elevator is absolutely safe from falling as the car is supported from beneath, and cannot go down faster than the water escapes from the cylinder. There is nothing to wear out except the packings, which can easily be renewed. The power is exerted **direct,** without intervention of **sheaves** or **cables** which insures the highest possible efficiency, and an absolute freedom from vibration. As the entire machinery is generally located in the basement under the elevator, no valuable floor space is occupied in the building. The simplicity of the machine, which has nothing to wear except the packings, makes it of very long life and great reliability. Its merits are summed up in its **safety, economy** of operation and **repairs,** smooth, quiet **running,** long life and **durability.**

SPECIFICATIONS FOR STANDARD PLUNGER ELEVATOR.

The Standard Plunger Elevator Company hereby proposes to furnish and install—of the direct-acting plunger hydraulic type, together with pumping plant for same, as per the following specifications:

The service, runs, loads and speeds, sizes of plungers and cylinders, to be as per schedule below:

CYLINDER WELLS.

The cylinder wells will be of suitable size and shall be sunk by us into the ground under the hatchways to

proper depths by our improved rotary drilling or wet driving process, and the excavated material removed from the premises by us.

We shall furnish these wells with mild steel casing, set in place for their entire depths or until solid rock is encountered.

The water necessary for the drilling will be furnished by the owners at the regular street pressure, and they are also to furnish proper connections on the supply and sewer pipes for obtaining and disposing of this water by us.

CYLINDERS.

The cylinders of suitable length will be constructed of selected steel tubing having a large factor of safety, and will be protected from rust by a coating of asphalt or other preservative preparation.

All cylinder lengths are to be accurately straightened, squared, threaded and coupled so as to secure accurate alignment, and the cylinders are to be thoroughly tested by hydrostatic pressure before leaving the factory.

The cylinders will be closed at the bottom, and shall have stuffing boxes at the top accurately fitting the plungers, and provided with our improved plunger packing.

PLUNGERS.

The plungers will be of selected steel tubing, carefully straightened, turned and polished, of proper lengths, being so proportioned as to secure maximum lightness consistent with suitable strength. They shall be firmly secured to the platforms by platens, and the lower lengths of the plungers shall also be independently secured by our patent attachment to the platforms by inside bolts or cables. The sections are to be joined by our improved internal couplings, and each plunger is to be uniform in diameter and true in alignment. They are to be thoroughly gauged inside and out.

CONTROLLING VALVES.

The controlling valves for the passenger elevators and combination freight and passenger elevator will be our three-way balanced pattern, with brass linings and pistons, having independently graduated openings for stopping and starting so as to avoid shock or jar, and to secure maximum smoothness in the control of the cars.

The controlling valve for the freight elevator will be our three-way balanced pattern, with rack and pinion or lever control.

LEVER AND CONNECTIONS.
THE CONTROLLING AND AUTOMATIC STOP APPARATUS.

Each passenger elevator car and the combination freight and passenger elevator car will be provided with a controlling lever having center stop notch, which shall be connected by our double controlling valves.

OVERHEAD BEAMS FOR COUNTER WEIGHTS.

The overhead supporting beams will be of steel of suitable section, furnished, erected and firmly secured in position by us upon proper supports provided by the owners in the construction of the hatchways.

PILOT VALVES.

The controlling valves for the elevator shall be governed in their motion, both in direction and extent, by pilot valves, thus securing a positive control from the lever in the car at all speeds.

AUTOMATIC LIMITATION STOP VALVES.

Each elevator will be provided with our automatic limitation stop valves, operating independently of all other mechanism, which brings the car to a gradual stop at the upper and lower terminals of travel, whether controlled by the operator or not.

QUESTIONS AND ANSWERS.

Q. How are elevators usually **classed**?

A. In reference to the motive power used, as belt steam, electric and hydraulic elevators.

Q. What do you mean by **overbalancing** an elevator?

A. Making the counterweight **heavier** than the full weight of the car.

Q. Into what two classes are **safety devices** divided?

A. Into **motor** safeties and **car** safeties.

Q. By what different means is the **brake** operated on **electric** elevators?

A. By mechanical, electrical-mechanical or entirely electrical attachments.

Q. What **sets** and what **releases** the brake on an electric magnet control elevator?

A. A spring or weight sets the brake, and a **solenoid** releases it.

Q. What is a **plunger** elevator?

A. One in which the car is placed directly on top of the plunger or piston.

Q. What is the purpose of a **pilot** valve?

A. To give **better** control of the main controlling valve.

Q. Why **cannot** a plunger elevator be overbalanced?

A. Because the power acts only during the up **stroke** of the elevator.

). What is the **advantage** of overbalancing an elec-
?

. It permits a **smaller** motor to be used.
). How should the rope always be **fastened** to the
?

. It should be made long enough to encircle the
at least **twice** when the elevator is in its **lowest**
on.

. What is meant by the **limit stops** on an ele-
?

. The safety devices used to automatically stop
r at the **upper** or **lower** limit of its travel.
. What limit stops are usually placed on the
r rope?
. **Buttons** or **knobs** against which the car strikes,
g the belt to be shifted, or power cut off. Such
s or knobs are not sufficient protection in them-
as they are apt to **slip** or **break.**
. What is the most common form of **motor limit**

. A **gear wheel** working loosely on an extension
drum shaft. Should the car overrun its limit,
on the up or down trip, jaws on the hub of the
gear engage with jaws fastened to the threaded
causing the loose wheel to rotate. This sets in
ion the **gear** which turns the shipper sheave,
y **reversing** the motion of the elevator.
. How is the engine of an ordinary spur gear
elevator **reversed?**
. By the use of a **reversing** valve, the valves of
gine being changed from **direct** to **indirect** valves.
. What is a **slack cable** device as used on all
elevators?
. A device for **stopping** the car should the cable
ose, or the car stick in its descent. It usually con-
of a rod extending across the **underside** of the
g drum. Upon the loose cable striking it, a spring
ght is **released,** causing the steam to be shut off.

CHAPTER XXVIII.

THE STEAM ENGINE INDICATOR.

Definition.—The indicator is an instrument used to indicate the amount of **pressure** in the cylinder of an engine, and also to indicate the exact **location** of the piston when that pressure exists. From this can be told not only the **distribution** of the steam pressure throughout the stroke of the piston, but also the **action** of the valve gear.

The obtaining of this knowledge by means of the indicator has been of the greatest assistance in the development of the steam engine.

Construction.—This instrument as invented by Watt consisted simply of a small piston working in a cylinder, which cylinder was a minature of the larger cylinder whose performance was desired to be known.

The movement of the spring due to the steam pressure on it, was shown by the tracing of a pencil on a piece of paper made to move simultaneously with the piston of the engine. Later, a drum on which the paper was attached was adopted.

With the single exception of **multiplying** the movement of the indicator spring by using a lever, which permitted a stiffer spring to be used, there has been no change in the general construction of the indicator since its invention.

By using a stiffer spring than was employed by Watt, the movement of the indicator piston was lessened, which therefore required its movements to be multiplied, i. e., **increased,** so that the diagram, or card as it is called, made by the movement of the pencil on the paper, would be increased to a sufficient size so as to be readily understood.

The indicator is therefore an instrument which is employed to give a correct idea of all that takes place in the cylinder.

It consists of a small cylinder accurately bored out and fitted with a piston, which works in the cylinder with little or no friction, and yet is practically steam-tight.

The piston has an area of just one-half of a square inch, and its motion or travel in the cylinder, is only 25/32 of an inch.

The piston rod is connected to a pair of light levers, so linked together that a pencil carried at the center of the link moves in nearly a straight line through a maximum distance of $3\frac{1}{8}$ inches. A spiral spring placed in the cylinder above the piston resists the motion of the piston, and the elasticity of this spring is such that each pound of steam pressure on the piston causes the pencil to move the fractional part of an inch. As the steam pressure that exists each instant in the cylinder of the engine is the same as the pressure on this spring, the pencil, which records the movements of the spring, will accurately record the **pressure** in the cylinder. This is the fundamental principle on which all indicators operate.

The pencil is usually made of a piece of pointed brass wire which makes a well defined line upon the paper especially prepared for indicator work.

This paper is wound around the drum, which has a diameter of 2 inches, and is capable of a semi-rotary motion upon its axis to such an extent that the extreme length of the diagram may be $5\frac{1}{4}$ inches. While these dimensions are those of the most generally used indicator, they are slightly varied for different character of work, the drum frequently being made only $1\frac{1}{2}$ inches.

Motion is given to the drum in one direction, during the forward stroke of the piston, by means of a cord connected indirectly to the cross-head of the engine, the drum being brought back again during the return stroke of the piston, by the action of a coiled spring at its base.

The **upper** side of the piston is open to the atmosphere, while the **lower** side may be put in communication either with the atmosphere, or with either end of the engine cylinder.

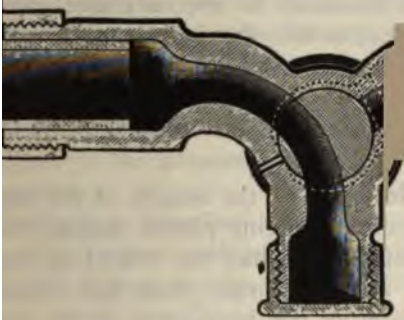
This is done by means of a three-way cock, such as shown in Fig. 262, a quarter turn of the handle placing either end of the cylinder in connection with the indicator.

When **both** sides of the piston are pressed upon by the atmosphere, there is no pressure on the spring other than the atmospheric pressure, and the pencil on being brought into contact with the moving paper describes what is known as the **atmospheric line.**

When the lower side of the piston is in communication with the engine cylinder, the pressure of the steam therein then acts upon the indicator piston; and on the pencil being pressed against the paper during a complete double stroke of the engine, the entire indicator diagram is described.

Essential Parts.—The four essential parts of the indicator are therefore; the cylinder, the spring, the piston with its connections, and the drum.

To attach the Indicator to the Engine.—All first class engines are prepared for the indicator before leaving the factory. Should this not have been done, then **each** end of the cylinder must be drilled and tapped for a one-half inch pipe thread. The holes must be drilled into the **clearance space,** so that the piston at the ends of the stroke will not cover them. They should also be



A Three-Way Cock.
Fig. 262.

placed so that currents of steam will not reach them. The holes should be drilled into the **middle** of the clearance space, the engine being placed on dead center in order to determine the clearance.

For **horizontal** engines the holes are drilled in the side of the cylinder at each end; while for **vertical** engines, the upper head or cover and the side of the cylinder are selected for the upper and lower indicators respectively.

Where it is necessary to use only **one** indicator for both ends of the cylinder, the indicator should then be connected by side pipes, and a three-way cock used to make connection with the two ends. By this method both diagrams are taken on the same card, and with the loss of but one revolution.

Reducing Motion.—As the length of the card represents the **travel** of the engine piston, and as the length of the card is much less than the travel of the piston since the stroke is much longer than the circumferenc of the drum; therefore the movement of the cross-heac which actuates the drum, must be reduced to the lengt of the diagram. While it is not necessary to use th cross-head for the operation of the drum of the indicator since it has many advantages for this purpose, it is generally used.

But whether the cross-head or some other part o the engine is selected, there must be a **reduction** of th movement of same to the length of the diagram, an there are several devices employed to obtain this reduce motion; such as the pantograph, lazy tongs, Brumb pulley, reducing wheel, etc.

Uses of the Indicator.—It is principally used, (1) t measure the power of the steam engine; (2) to show th quantity of steam used per horse power for a given time

3) to indicate how to adjust the valve gear of the en-ine; (4) the vacuum obtained by the use of the con-enser; and (5) the relative pressure existing between e steam in the boiler and the pressure of the steam in e cylinder.

Indicator Card or Diagram.—The tracing of the pen- on the paper of the indicator, is called a **card** or **dia-am,** and is the result of the horizontal and vertical mo-ns of the indicator. The **horizontal** movement of the per corresponds exactly to the movement of the **piston;** this motion is produced by the movement of the cross-ad which rotates the drum by means of the cord at-ched to it.

The **vertical** movement of the pencil, is in exact tio to that of the **pressure** of the steam in the cylinder the engine.

The diagram therefore represents by its **length,** the roke of the engine; and by its **height,** the steam pres-re on the piston at the corresponding point of the roke.

Suppose a valve has **no lap,** the steam would then be mitted to the cylinder during the **whole stroke,** that is, e end of the engine cylinder is in communication with e boiler during the **entire** stroke of the piston. Now, the indicator is placed in communication with the linder during this stroke of the piston, the diagram or rd will show a **rectangle,** as can be seen from the fol-wing illustration.

If we draw two lines at right angles to each other, e horizontal line will represent the **volume** of the eam, while the vertical line will represent the **pressure.** s both the volume and the pressure will remain the me during the entire stroke of an engine taking steam ll stroke, these lines will be perfectly **straight,** and at

right angles to each other. In Fig. 263 is shown the diagrams of an engine taking steam at full stroke.

There are but few modern engines that take steam full stroke, it being too wasteful of steam. Steam is admitted during **part** only of the stroke, the communication to the boiler being then cut off, and the steam in the cylinder being allowed to **expand** as the piston moves forward until it fills the entire volume of the cylinder. What then takes place in the cylinder is represented graphically by the diagram shown in Fig. 263.

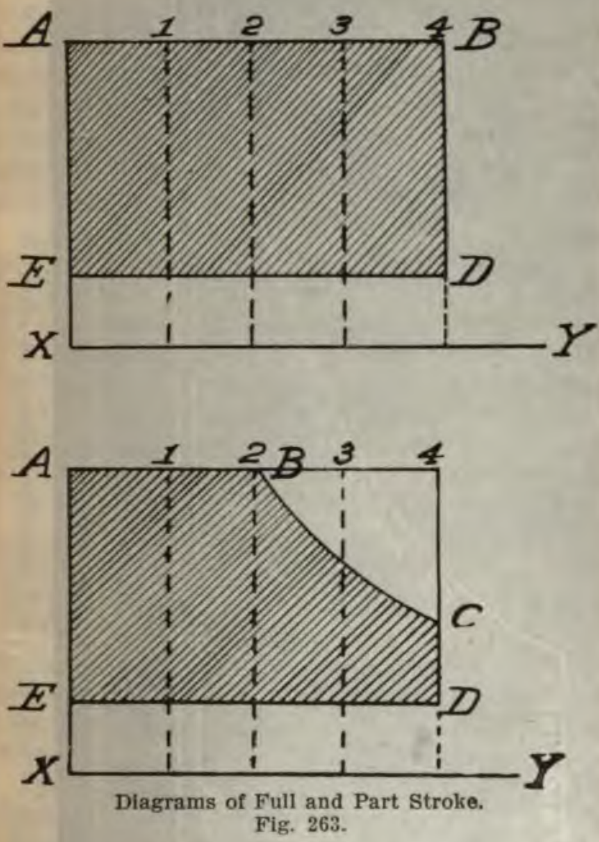
Steam is admitted to the cylinder until the piston reaches the point B, which represents one-half the volume of the cylinder. Then the cylinder is half full of steam, but from this point on as no more steam is admitted, and as the volume continues to **increase**, the pressure must **diminish**. The dimunition in the pressure is shown by the curved line B. C., which is called the **expansion line.** This curve should be almost an equilateral hyperbola.

The exhaust valve opens at the point C, releasing the pressure acting on the piston; and in consequence the pressure is also released on the indicator spring, thereby causing the pencil to make the vertical line C. D.

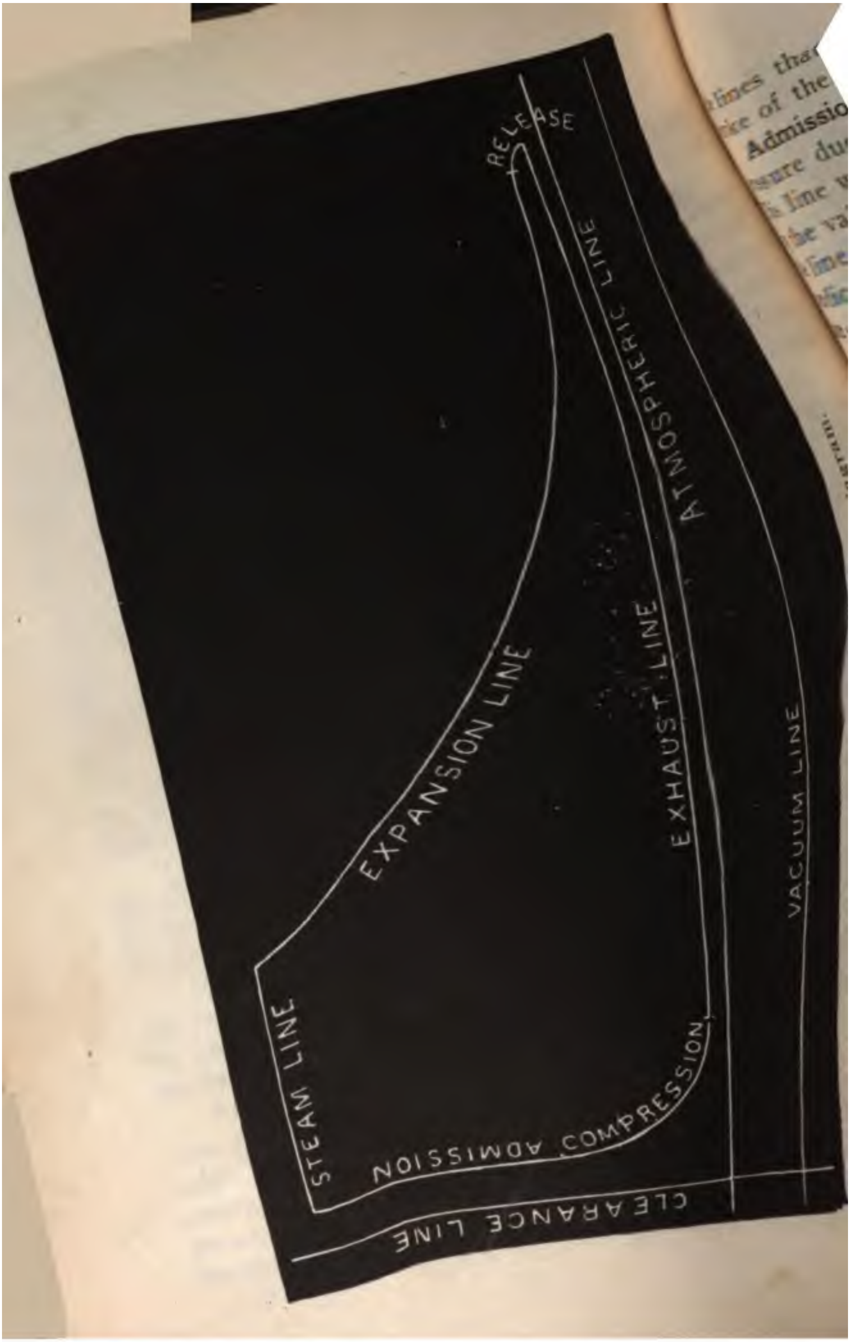
The piston then starts on its return stroke, and as the only back-pressure acting on it is the pressure of the **atmosphere,** the pencil traces the line D. E., called the **back-pressure line.**

As there is no lead to the valve, and no compression, the line D. E. will meet the line E. A. at a right angle. Should there have been **compression,** then the pressure would have produced a curved line, such as shown in Fig. 264, the curve there shown being called the **compression line.**

In Fig. 264 is shown an **ideal** diagram, in which all



Diagrams of Full and Part Stroke.
Fig. 263.


RELEASE
EXPANSION LINE
ATMOSPHERIC LINE
EXHAUST LINE
VACUUM LINE
STEAM LINE
ADMISSION
COMPRESSION
CLEARANCE LINE

the lines that are traced during the forward and return stroke of the piston, are given their usual designation.

Admission Line.—This line shows the **rise** of the pressure due to the admission of steam to the cylinder. This line will be **vertical** if the steam is admitted **quickly** by the valve when the engine is nearly on center. Should the line curve to the left or right from a vertical or perpendicular position, it is due to the valve opening **too late** or **too early**, as the case may be.

Steam Line.—This line is drawn during the time the valve admits steam to the cylinder. It will be a **horizontal** line unless the steam is **wire-drawn,** in which event it will be **diagonal,** that is, it will have a **downward** inclination.

Cut Off.—The point at which the admission of steam is stopped by the closing of the valve, is shown by the sudden drop in the steam line. Since the valve closes **slowly** this point will be rounded, and at times hard to detect, but its position can always be determined by remembering it is the point where the curve **changes** from concave to convex.

Expansion Curve.—This line shows the **fall in pressure** as the steam expands while the piston moves towards the end of the stroke. As the volume occupied by the steam in the cylinder **increases,** the pressure **decreases.**

Point of Release.—This is the point at which the exhaust valve opens. It is always a rounded point due to the slow action of the valve in opening. This exhaust curve begins a little before the end of the forward stroke, which is also due to the slow action of the vale in opening.

Exhaust Line.—This line, or curve, shows the loss in pressure when the valve opens to exhaust.

Compression Curve.—
pressure due to the compr
in the cylinder after the val

Atmospheric Line.—T
gram has been made and t
closed, and both sides of t
open to the atmosphere.
atmospheric pressure, whic
indicator piston. It is the
gauge.

The **height** of the back
shows the amount of the b
atmospheric pressure actin

The Zero or Vacuum
solute vacuum, and is dra
atmospheric line. The dis
line and this line therefor
sure.

Clearance Line.—Thi
to the line of absolute va
the end of the diagram eq
length of the diagram as

eam, thereby causing the horizontal lines to be deflected ɔm their course. As the back-pressure in non-con-nsing engines is always **more** than atmospheric, the ck-pressure line is always **above** the atmosphere line. condensing engines, the vacuum is never absolute, ereby causing the vacuum line always to be **above** the ro line.

Practical Lines.—A few illustrations are here given that the student may familiarize himself with dia-ams most frequently seen in actual work.

Early Admission.—The admission line 1-2, diagram Fig. 265, indicates **too early** admission, as this line ırves to the left.

Late Admission.—The steam line 1-2-3, diagram 2, ıdicates **too late** admission, this line curving to the right.

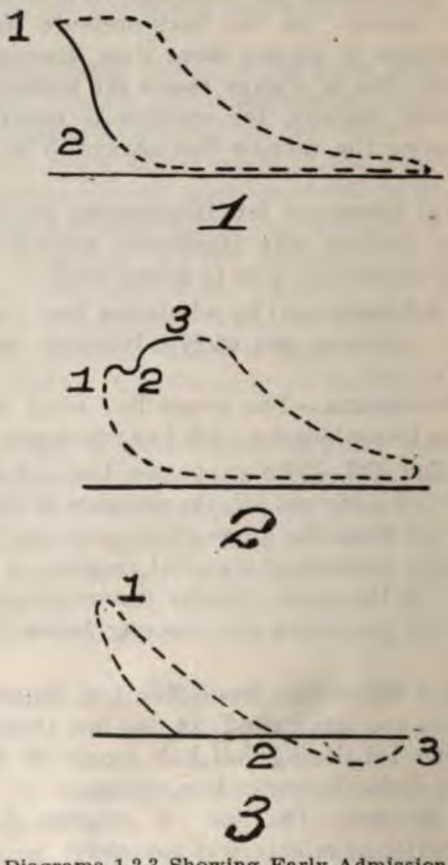
Early Cut Off.—The expansion line 1-2-3, diagram indicates too early cut off, the pressure in the cylinder ecoming less than the atmospheric pressure before re-ase; thereby producing a partial vacuum in the cylin-er formed by the rapid cylinder condensation. This is ıown by the expansion line running **below** the atmos-heric line.

Late Cut Off.—The steam line 1-2, diagram 4, Fig. 66, indicates **too late** cut off, as this line shows that ad-ıission extended during full half stroke of the piston. 'his diagram also indicates **late release.**

Early Release.—The line 1-2, diagram 5, indicates hat the point 1 of release was too early.

Late Release.—The line 1-2-3, diagram 6, indicates oo late release, the expansion having been continued to he point 1, and the release not taking place until the piston was on its **return stroke.**

Early Compression.—The line 1-2-3, diagram 7, Fig. 267, indicates too early compression, the pencil being



Diagrams 1-2-3 Showing Early Admission.
Fig. 265.

orced above the initial or boiler pressure, and falling ack as the piston of the engine commences its return roke; thereby forming the **loop** shown in the diagram.

Little Compression.—The compression line 1-2, diaam 8, indicates too little compression, as this curve ould be much more rounded.

No Compression.—In diagram 9 there is shown no npression whatever ,there being a corner or right an- at 1, in place of the usual curve.

Choked Admission.—The admission line 3-1, diagram Fig. 268, indicates by its slanting to the right that admission was late, due to the valve opening late. e steam line 1-2 indicates by its slant **downward,** an ufficient steam supply as the piston moves forward. is is due to the choking, or wire-drawing, of the steam m having too small ports.

Leaky Cut-Off.—The steam line 1-2, diagram 11, incates a leaky cut off, the point of cut off at 1 not being early defined.

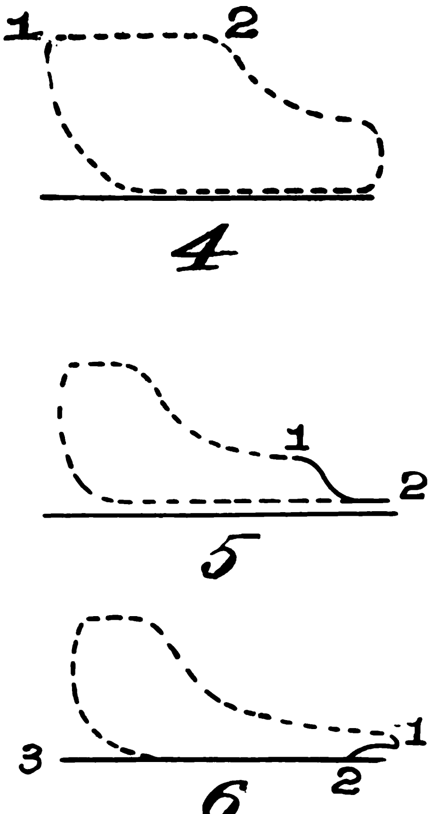
Choked Exhaust.—The exhaust line 1-2, diagram 12, dicates a choked exhaust, as the exhaust line indicates xcessive back-pressure on the return stroke of the pison, thereby making the point 2 at which release takes lace much too high.

Excessive Back Pressure.—The exhaust line 1-2, diaram 13, Fig. 269, indicates excessive back-pressure, the ne being too high above the atmospheric line, which ntinues the whole length of the return piston, there eing no fall or curve at the release point 2.

Double Admission.—The steam line 1-2-3, diagram , indicates **double admission,** due to **leakage** or **irreguity** of the valve motion.

Eccentric Slipped Back.—In diagram 15, the eccenic is shown slipped back. All the lines show the events

[redacted]



Diagrams 4-5-6 Showing Late Cut Off.
Fig. 266.

in the steam distribution to be late. Instead of the admission line being vertical, it curves to the right.

Eccentric Too Far Ahead.—In diagram 16, Fig. 270, he eccentric is too much ahead of the crank, i. e., the ingle of advance is too great, causing all the events in he steam distribution to take place **too early.**

The admission line 1-2 curves to the left; there is lso but little of a steam line, while the release is so arly that there is **no** exhaust line.

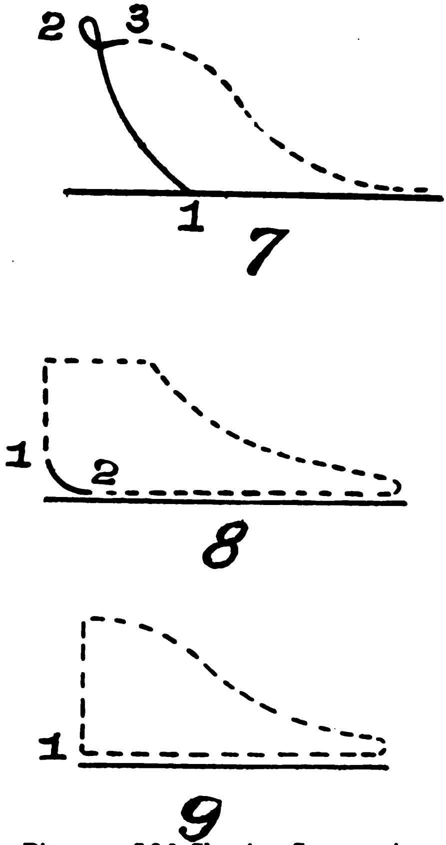
Indicator Inertia.—The line 1-2-3, diagram 17, indiates by the **waves** in the curve, the inertia of the indiator spring. The line 1 in diagram 18 also indicates iertia.

In Fig. 271, diagram 1, the line shown comprises oth the compression and admission lines. This admision line indicates that the pressure runs up suddenly to ull pressure, the line being perpendicular as it should e. To secure this line the steam valves must open fully efore the piston begins its stroke. Should the valve pen too soon, this line will curve to the left; if on the ontrary the piston begins its stroke before the valve pens, then the pressure in the cylinder will not be full ressure, and this line will curve to the right. The mount of **lead** will determine to a great extent the charcter of this line.

Should there be considerable lead, thereby increasig the compression; then the compression curve will ave the appearance shown in diagram 2.

Diagrams 3 and 4, indicate that the piston started on s return stroke **before** the valve opened to admit steam, hereby curving the admission line to the right from a erpendicular position, showing that the valve opened too ite. The angle of advance of the valve must therefore e increased.

[redacted]



Diagrams 7-8-9 Showing Compression.
Fig. 267.

In Fig. 272 is shown several more types of admission and compression lines.

In diagrams 1 and 2, the **loop** in the compression line is caused by the piston starting before the valve opens, causing the compression to run up and then suddenly fall ack as the piston moves forward.

In diagrams 3 and 4 are from cards taken off a high peed engine with a shaft governor. The loop in these iagrams is caused in the same way as previously shown, e., by the compression becoming **greater** than the initial boiler pressure, and suddenly **decreasing** when the alve opened.

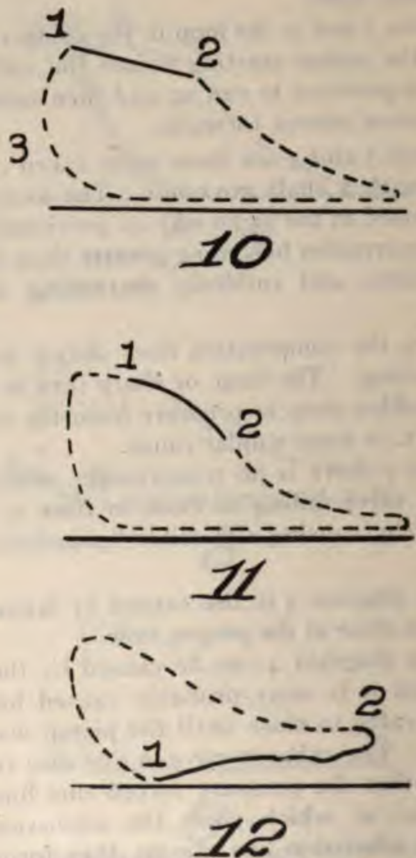
In Fig. 273, the compression lines shown are due to ulty valve setting. The loop, or sharp turn in diagram is due to a sudden drop in pressure from the valve **lifting** from its seat, or some similar cause.

In diagram 2 there is no compression, which is due o the exhaust valve failing to close in time to cushion the steam, thereby causing a possible "pounding" of the engine.

The line in diagram 3 is also caused by failure of the exhaust valve to close at the proper time.

The loop in diagram 4 can be caused by the eccentric slipping, but it is more probably caused by failure of the exhaust valve to close until the piston was on its forward stroke. The exhaust valve in this case remained closed so long that the pressure forced this line below the exhaust line, at which point the admission valve opened and the admission line ran up, thus forming the loop.

In Fig. 274, the sharp point in diagram 1 indicates too much lead, causing the pressure to run up above the initial pressure and causing the steam line to quickly drop, thereby forming the sharp point or corner.



Diagrams 10-11-12 Showing Choked Admission; Leaky C
Choked Exhaust.
Fig. 268.

The loop shown in diagram 2 indicates too early cut off, thereby permitting the pressure to drop below the atmospheric pressure. This can be remedied by either **reducing** the boiler pressure, or making a later cut off. The latter is not advisable, as it will lower the **efficiency** of the engine. The defects in the other diagrams of this figure are apparent.

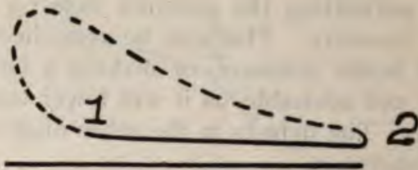
Valve Setting with Indicator.—The diagram shown in Fig. 275 indicates too early admission. The cut off, release and compression are all too early. We therefore presume this card is taken off a plain slide valve engine, and that the valve has too much angular advance, and hence it must be decreased.

In Fig. 276 the admission is **late**, as well as all the other events in the steam distribution. We therefore must **increase** the angular advance of the valve until the admission line is perpendicular to the atmospheric line.

In Fig. 277 is shown the diagram of a valve having too **late** a cut off, thereby causing a very high pressure at release.

By making this valve cut off **earlier**, more expansion can be obtained from the steam, and the pressure at release also becomes much **less**.

To Find the Area of Cards.—As we have seen, in order to find the **horse power** of an engine it is necessary to know the **mean effective pressure**, that is, the **average** pressure acting on the piston throughout the stroke. It is for finding this mean effective pressure that the indicator is mostly used by engineers. This mean effective pressure is equal to the **area** of the indicator diagram divided by the **length**. The **length** is easily found by measuring it, but it is much more difficult to find the **area**, as the card assumes so many different shapes.



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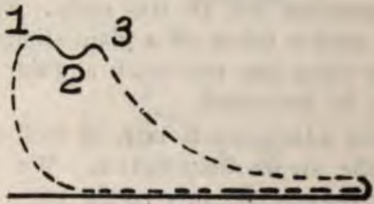

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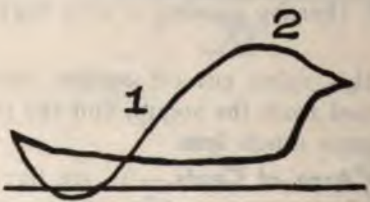


15

Diagrams 13-14-15 Showing Excessive Back Pressure; Double A mission; Eccentric Slipped Back.

Fig. 269.

Area.—The **area** of the indicator card can be found in two ways, viz.: (1) by dividing the diagram into sections, and (2) by the use of a planimeter.

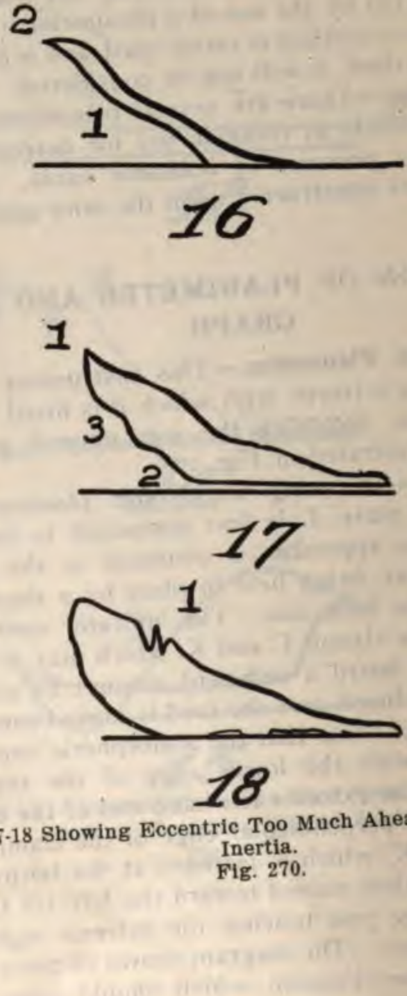
As the former method is rarely used, and is only an approximate method, it will not be considered.

Planimeter.—There are several planimeters and averging instruments in common use for determining the mean effective pressure of indicator cards. All these instruments are constructed upon the same general principles.

DESCRIPTION OF PLANIMETER AND PANTOGRAPH.

The Coffin Planimeter.—This instrument is operated by moving a tracer, with which it is fitted, over the line of diagram, recording the area upon a graduated wheel, as is illustrated in Fig. 278.

Operation.—In using the Coffin planimeter, **the** grooved metal plate, I, is first connected to the board upon which the apparatus is mounted, in the position shown in the cut, being held in place by a thumbscrew applied from the back side. The indicator card is then placed under the clamps C and K, which may be sprung away from the board a sufficient amount to allow the card to be introduced, and the card is moved toward the left into such a position that the atmospheric line is near to and parallel with the lower edge of the stationary clamp C, while the extreme left-hand end of the diagram is even with the perpendicular edge of the clamp. The movable clamp K, which is fastened at the bottom to a sliding plate, is then moved toward the left, till the vertical beveled edge just touches the extreme right-hand end of the diagram. The diagram shown in the cut represents the proper location which should exist when



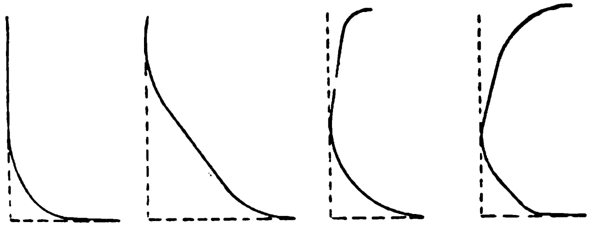
16-17-18 Showing Eccentric Too Much Ahead; Indi[illegible]
Inertia.
Fig. 270.

these preliminary adjustments have been completed. The slide at the bottom of clamp K fits closely, so that the application of a slight pressure with the thumb or finger is required to displace it.

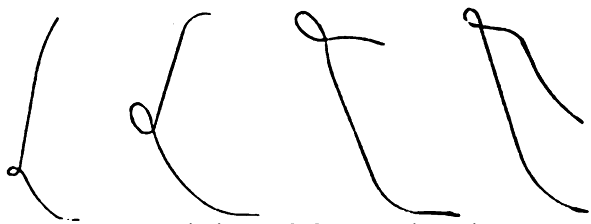
The beam of the instrument is next placed on the board, with the pin at the lower end resting in the groove I, and the weight Q applied to the top of the pin so as to keep it securely in place. The tracer O is moved to the right-hand end of the diagram and set at the point D, on the line of diagram, where the clamp K and the diagram touch each other. Here a slight indentation is made in the paper by pressing the finger on the top of the tracer, and this serves as a starting point. The graduated wheel is next turned so as to bring its zero mark to the zero mark on the vernier. The instrument is now ready for operation. The tracer O is carefully moved over the line of the diagram, in the direction of motion of the hands of a watch, and continued till a complete circuit is made and the tracer finally reaches the starting point D. Keeping the eye on the wheel, the tracer is now moved upward by sliding it along the edge of the clamp K, until the reading on the wheel returns to zero. Another light indentation is made on the paper to mark the new position which the tracer occupies. This point is represented at A in the cut. The instrument is now moved away, the clamp pushed back, and the distance between the two points D and A is measured with a scale corresponding to the number of the spring used in the indicator. The distance thus found is the mean effective pressure, expressed in pounds per square inch of piston.

The **Coffin planimeter** determines the desired result without computation, but it may be used also for determining the area enclosed by the diagram. This area is

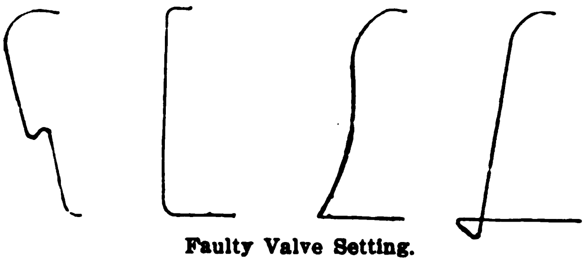
[redacted]



Admission and Compression Lines.
Fig. 271.



Admission and Compression Lines.
Fig. 272.



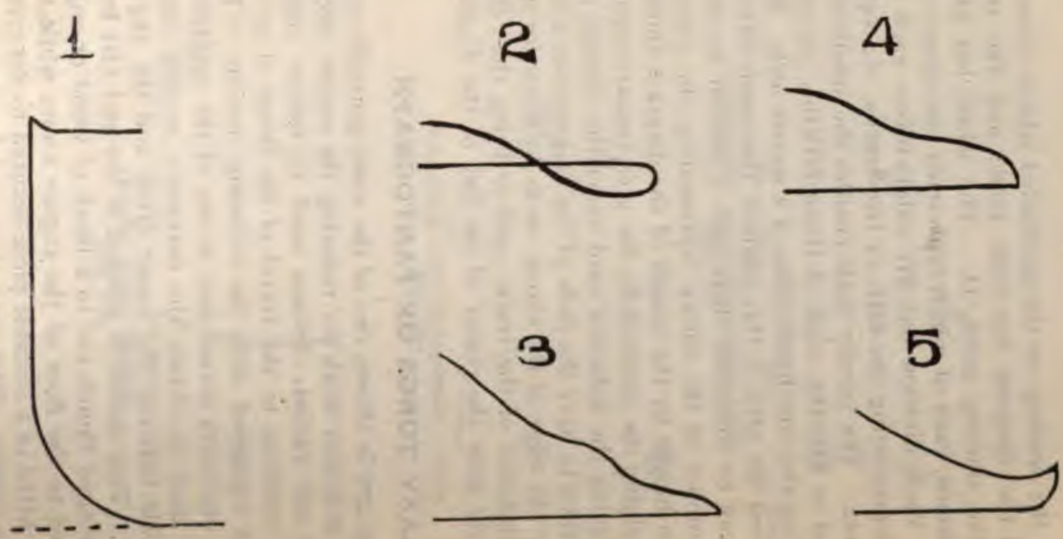
Faulty Valve Setting.
Fig. 273.

iven by the reading on the graduated wheel, when the ircuit of the diagram has been made and the tracer eaches the starting point, D. The wheel has fifteen ain divisions, each of which represents one square inch f area. Each division has five subdivisions, each sub-vision representing one-fifth, or two-tenths, of a square ch of area. The vernier scale enables the subdivisions be read to fiftieths, each of these fiftieths, therefore, presenting two one-hundredths of a square inch. Hav-g obtained the area in this manner, the mean effective essure can be computed therefrom, if desired, by divid-g the number of the spring representing the pressure r inch in height by the length of the diagram (inches) d multiplying the quotient by the area (square inches). first placing the indicator card under the clamps, care ust be taken to have the ends of the diagram set a little vay from the edge of the clamp, so as to allow for one-lf the diameter of the tracer, and to bring the center the tracer over the center of the line of the diagram.

LAZY TONGS OR PANTOGRAPH.

In Fig. 279 is shown one of the most generally used evices in indicator work for reducing the engine stroke.

There are various devices used to reduce engine rokes to conform to the travel of the drum of an in-cator not equipped with the reducing motion. The ove cut, one-sixth actual size, is one of the appliances equently used to obtain the necessary motion (on a duced scale between the paper drum and the engine oss-head. This device is pivoted at the end (B) by a d and winged thumb nut to a block of wood or angle n secured to the floor of the engine room, while the d (A) is fitted in a suitable piece secured to the cross-ad of the engine. The actuating cord from the indi-



Diagrams Showing Faulty Valve Setting.
Fig. 274.

ıtor is attached to the cord pin (E) on the cross-bar C D). This cross-bar may be moved in different posi-ons with relation to the center (B) by changing the crews (C and D), and the cord-pin (E) must always be laced in a line with the centers (A and B). The posi-ion of the cross-bar (C D) in relation to (B) determines he length of travel of the cord-pin (E), and consequently he length of the diagram.

This lazy tong can be used to obtain any desired eduction of motion of the engine piston, of various ength strokes up to 72 inches.

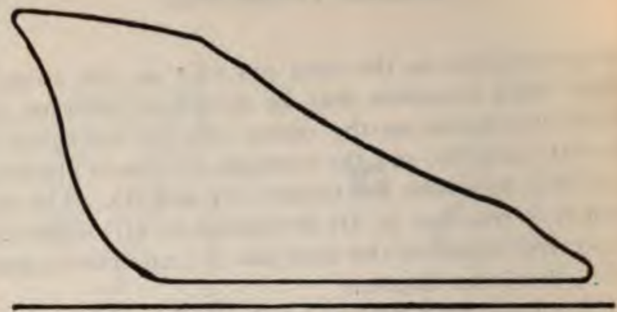
THE CROSBY STEAM ENGINE INDICATOR.

Construction.—Fig. 280 shows the design and arrangement of the parts of the Crosby steam engine indicator.

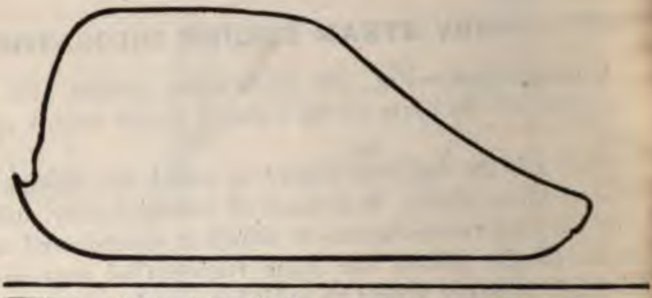
Part 4 is the cylinder proper, in which the movement of piston takes place. It is made of a special alloy, suited to the varying temperatures to which it is subjected, and secures to the piston the same freedom of movement with high pressure steam as with low; and as its bottom end is free and out of contact with all other parts, its longitudinal expansion or contraction is unimpeded, and no distortion can take place.

Between the parts 4 and 5 is an annular chamber, which serves as a steam jacket; it will always be filled with steam of nearly the same temperature as that in the cylinder.

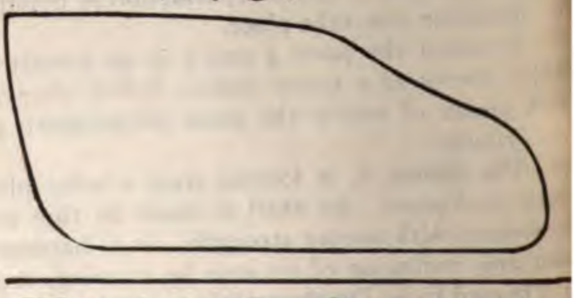
The piston, 8, is formed from a solid piece of the finest tool steel. Its shell is made as thin as possible consistent with proper strength. It is hardened to prevent any reduction of its area by wearing, then ground and lapped to fit (to the ten-thousandth part of an inch) a cylindrical gauge of standard size. Shallow channels



TOO EARLY ADMISSION
FIG. 275.



TOO LATE ADMISSION.
FIG. 276.



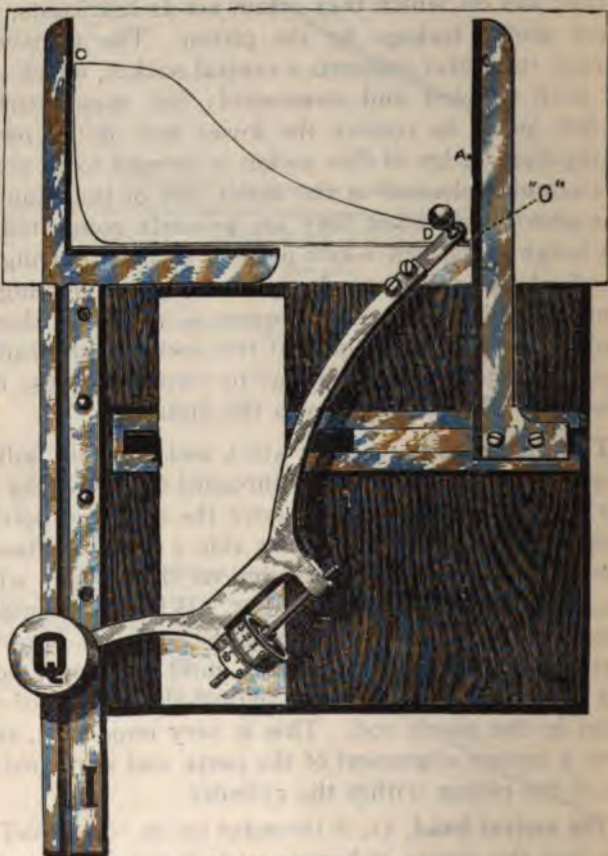
TOO LATE CUT OFF.
FIG. 277.

its outer surface provide a steam packing, and the oisture and oil which they retain act as lubricants, and event undue leakage by the piston. The transverse eb near its center supports a central socket, which pro-cts both upward and downward; the upper part is readed inside to receive the lower end of the piston d; the upper edge of this socket is formed to fit nicely to a circular channel in the under size of the shoulder the piston rod, when they are properly connected. It as a longitudinal slot which permits the ball bearing on e end of the spring to drop to a concave bearing in e upper end of the piston screw 9, which is closely readed into the lower part of the socket; the head of is screw is hexagonal, and may be turned with the hol-w wrench which accompanies the indicator.

The piston rod, 10, is of steel, and is made hollow r lightness. Its lower end is threaded to screw into the pper socket of the piston. Above the threaded portion a shoulder having in its under side a circular channel rmed to receive the upper edge of the socket, when ese parts are connected together. When making this nnection the piston rod should be screwed into the cket as far as it will go, that is, until the upper edge the socket is brought firmly against the bottom of the annel in the piston rod. This is very important, as it sures a correct alignment of the parts, and a free move-ent of the piston within the cylinder.

The swivel head, 11, is threaded on its lower half to rew into the piston rod more or less according to the quired height of the atmospheric line on the diagram. s head is pivoted to the piston rod link of the pencil echanism.

The cap, 2, screws into the top of the cylinder, and olds the sleeve and all connected parts in place. Its

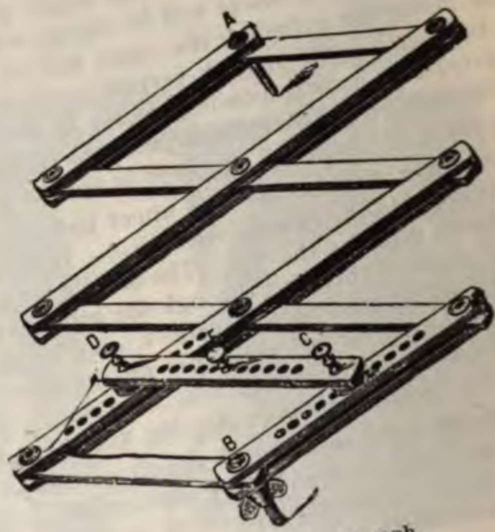


The Coffin Planimeter.
Fig. 278.

ral hole is furnished with a hardened steel bushing ch forms a support and a guide to the piston rod. On ınder side are two threaded portions. The lower and ller projection is screw-threaded outside to engage h the like threads in the head of the spring, and hold irmly in place. The upper and larger projection is ew-threaded on its lower half to engage with the light eads inside the cylinder; the upper half of this larger jection—being the smooth vertical portion—is accurly fitted into a corresponding recess in the top of the inder, and forms thereby a guide by which all the ving parts are adjusted and kept in correct alignment.

The sleeve, 3, surrounds the upper part of the cylin-, and supports the pencil mechanism. It turns freely, d is held in place by the cap. The handle for adjusting pencil point is threaded through the arm, and in con-t with a stop screw in the plate, 1, may be delicately usted to the surface of the paper on the drum. It is de of hardwood in two sections; the inner one may used as a lock-nut to maintain the adjustment.

The pencil mechanism is designed to afford suffint strength and steadiness of movement, with the htness; thereby eliminating as far as possible the effect momentum, which is especially troublesome in highed work. Its fundamental kinematic principle is that the pantograph. The fulcrum of the mechanism as whole, the point of attachment to the piston rod, and pencil point, are always in a straight line. This gives the pencil point a movement exactly parallel with that the piston. The movement of the spring throughout range bears a constant ratio to the force applied, and amount of this movement is multiplied six times at pencil point. The pencil lever, links and pins, are made of hardened steel; the latter—slightly tapering—



Lazy Tongs or Pantograph.
Fig. 279.

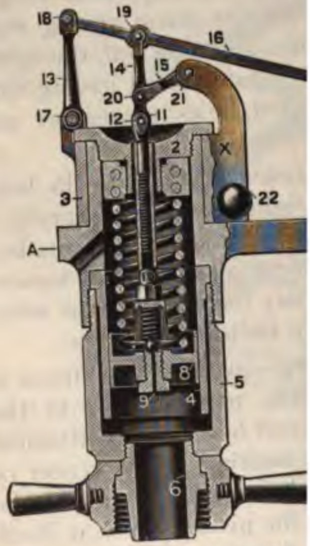
are ground and lapped to fit accurately, without perceptible friction or lost motion.

Springs.—In order to obtain a correct diagram, the movement of the pencil of the indicator must be exactly proportional to the pressure per square inch on the piston of the steam engine at every point of the stroke; and the velocity of the surface of the drum must bear at every instant a constant ratio to the velocity of the piston.

The piston spring is of unique and ingenious design, being made of a single piece of the finest spring steel wire, wound from the middle into a double coil, the spiral ends of which are screwed into a brass head having four radial wings with spirally drilled holes to receive and hold them securely in place.

Adjustment is made by screwing them into the head more or less until exactly the right strength of spring is obtained, when they are there firmly fixed. This method of fastening and adjusting removes all danger of loosening coils, and obviates all necessity for grinding the wires —a practice fatal to accuracy in indicator springs.

At the bottom of the spring—in which lightness is of great importance, it being the part subject to the greatest movement—is a small steel bead, firmly attached to the wire. This bead has its bearing in the center of the piston, and in connection with the lower end of the piston rod and the upper end of the piston screw, 9 (both of which are concave to fit), it forms a ball and socket joint, which allows the spring to yield to pressure from any direction without causing the piston to bind in the cylinder, which is sure to occur when the spring and piston are rigidly united. It is of extreme importance that the spring be so designed that any lateral movement it may receive when being compressed shall not be communicated to the piston and cause errors in the diagram.



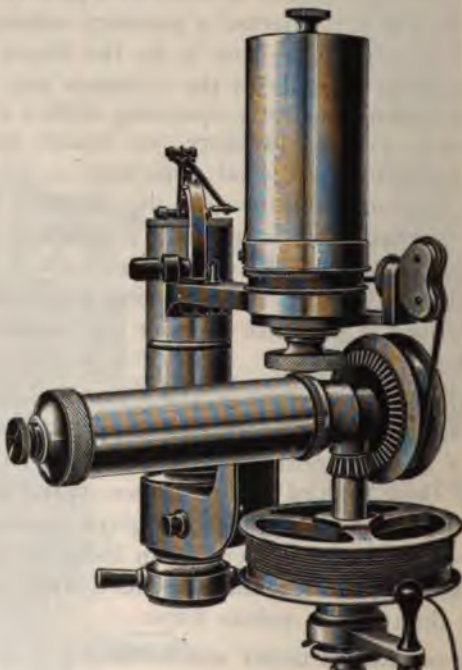
The 'Crosby

The Testing of the Spring.—The rating or measure-
ıt of the springs, both in vacuum and in pressure, is
ermined with great care and accuracy by special ap-
atus. The vacuum test is made by a powerful vacuum
np, to which is connected a mercury column marked
nches. The pressure test is by the direct action of
steam in the cylinder of the indicator and in a mer-
y column simultaneously operating with a capacity of
ee hundred pounds pressure per square inch. Suit-
e and ingenious electrical apparatus is so combined
h these mercury columns that the ordinary division in
hes of vacuum and in pounds pressure respectively
automatically marked on the test card on the indi-
or drum as the test of the spring proceeds. Each
ing is tested in pressure to twice the capacity marked
the same.

The drum spring, 31, in the Crosby indicator is a
rt spiral spring. It is obvious from the large contact
faces of a long volute spring, that its friction would
greater than that of a short, open, spiral form, also,
t in a spring of each kind, for a given amount of com-
ssion—as in the movement of an indicator drum—the
oil would be greater and expended more quickly in
spiral than in the volute form.

If the conditions under which the drum spring oper-
s be considered, it will readily be seen, that at the
inning of the stroke, when the cord has all the resist-
e of the drum and spring to overcome, the latter
uld offer less resistance than at any other time; in
beginning of the stroke in the opposite direction,
vever, when the spring has to overcome the inertia
friction of the drum, its energy or recoil should be
atest.

These conditions are fully met in the Crosby indi-



The Crosby Reducing Wheel.
Fig. 281.

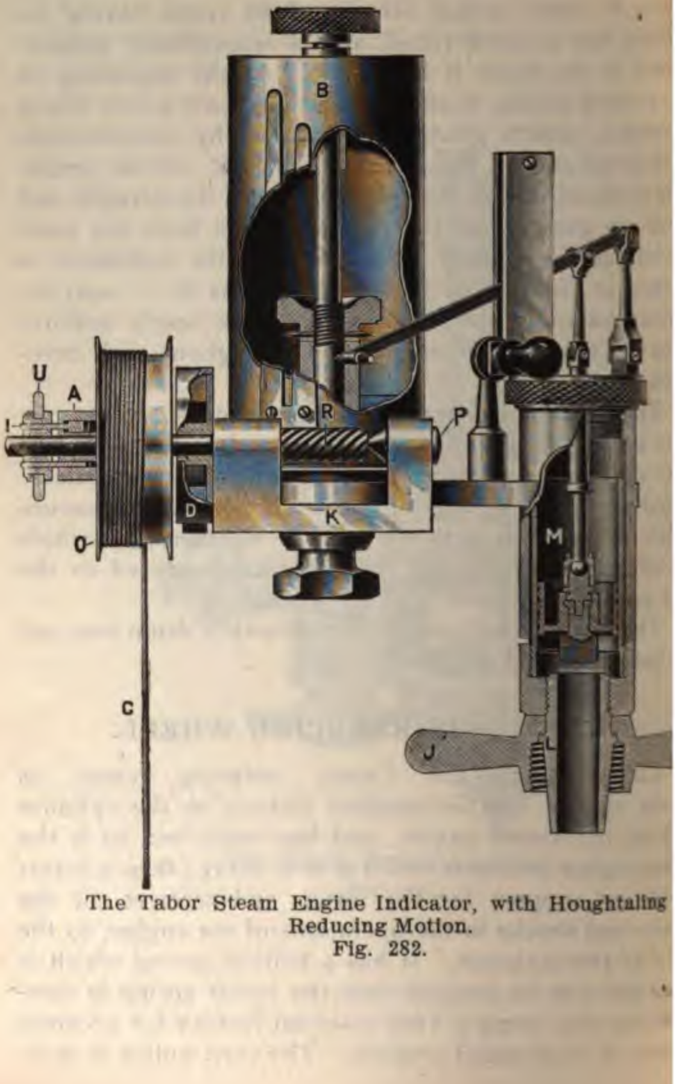
, its drum spring being a short spiral having no
ɔn, has a quick recoil, and is scientifically propor-
d to the work it has to do. At the beginning of
ɔrward stroke, it offers to the cord only a very slight
ance, which gradually increases by compression,
at the end its maximum is reached. At the begin-
of the stroke in the other direction, its strength and
l are greatest at the moment when both are most
ed, and gradually decrease until the minimum is
ɪed at the end of the stroke. Thus by a most in-
ɔus balancing of opposing forces, a nearly uniform
s on the cord is maintained throughout each revo-
n of the engine.

The drum, 24, and its appurtenances, except the
ı spring, are similar in design and function to like
of other indicators, and need not be particularly
ibed. All the moving parts are designed to secure
ient strength with the utmost lightness, by which
effect of inertia and momentum is reduced to the
possible amount.

The Crosby indicator is made with a drum one and
ıalf inches in diameter.

THE CROSBY REDUCING WHEEL.

Construction.—The Crosby reducing wheel, as
n in Fig. 281, is attached directly to the cylinder
of the steam engine, and has connected to it the
n engine indicator which it is to serve; thus it forms
se or support for the latter, and receives all the
ns and shocks in the operations of the engine, to the
of the indicator. It has a hellical spring which is
active in its purpose than the volute spring in com-
use, this being a very essential feature for accurate
ts on high-speed engines. The cord pulley is hori-



The Tabor Steam Engine Indicator, with Houghtaling Reducing Motion.
Fig. 282.

ontal, to allow the cord leading to the engine cross-head take any direction the circumstances may require, ithout regard to the position of the indicator.

Whenever the reducing wheel is to be attached to a ertical engine, an elbow nipple is provided which will llow the cord pulley to travel in the proper plane for uiding it to the cross-head of the engine, with the inicator in an upright position as usual.

Operation.—Attach it directly to the cylinder cock the steam engine by means of the union 4 of the stand-d 1. Connect the indicator to the standard 1 with the aper drum standing over the spring tube 14, and the inicator guide pulley in a proper position over the stroke ulley 20.

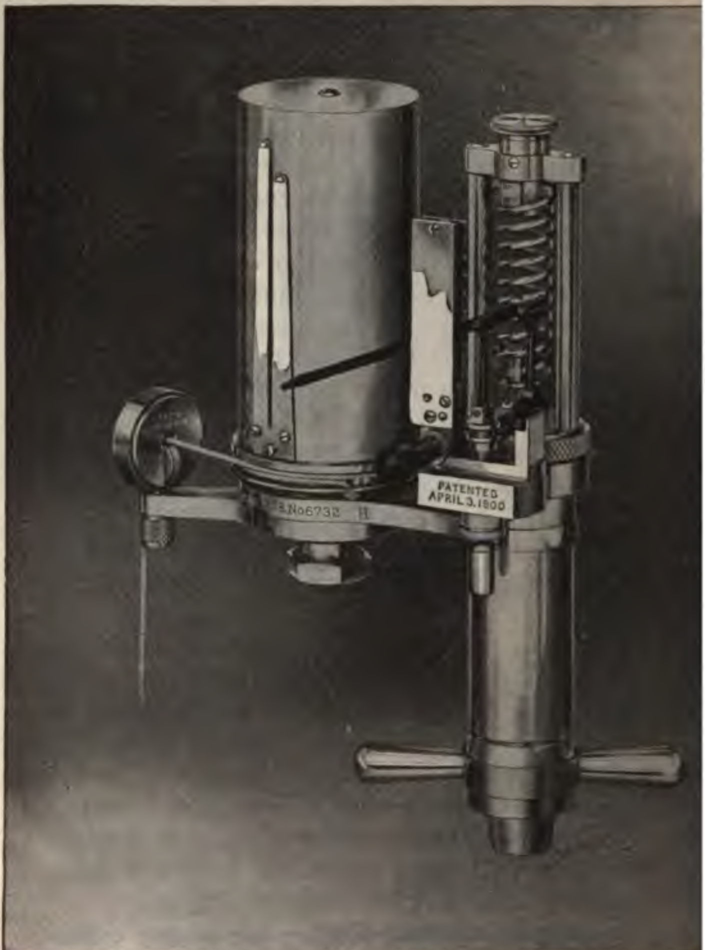
To Attach the Cord Guide.—Loosen the cord guide 4 by means of the screw beneath the cord pulley and ove it around to the proper position for the cord to ass directly through the hole in the cord guide without ibbing, to the cross-head of the engine; then tighten it place.

To Take Up the Tension Spring.—Release the umb screw 27 in the end of the shaft within the spring be 14; withdraw the knurled spring head 16 from its uare end, and turn it one or more squares as may be sired.

To Adjust the Stroke Pulley.—Remove the knurled sc 21 holding the stroke pulleys 20 in place on the gear aft; place thereon the stroke pulley desired; replace e disc, and screw it up firmly with the fingers.

To Attach the Indicator Cord.—Adjust the indicar cord one or more turns around the stroke pulley 20, assing the end through the hole in and around the hook the knurled disc 21.

When Used With Other Indicators.—Loosen the



The Tabor Indicator with Outside Spring.
Fig. 283.

lt 3 in the side of the standard 1 where it is attached the cylinder cock of the steam engine; remove the shing and insert another fitted to the indicator to be ed.

Important Suggestions.—In all cases the indicator rd should be of the right length to prevent the paper um from recoiling against its stop; and before attach- g it to the cross-head of the engine it should be drawn it its full length to ascertain whether or not the cords 1 the indicator and reducing wheel have been properly ljusted.

All the working parts must be kept well oiled.

The reducing wheel is adapted to be used with a eam engine indicator having either a 1½-inch or a 2- ich drum. As indicators with 2-inch drums are ordi- arily used, the reducing wheel will be provided only ith stroke pulleys for such size drum. If the reducing heel is to be used with an indicator having the 1½- ich drum, it should be so stated in order to receive the troke pulleys of the proper size.

'ABOR STEAM ENGINE INDICATORS WITH HOUGHTALING REDUCING MOTION.

Construction.—This patent **reducing motion,** as hown in Fig. 282, composed of a supporting base piece, K, provided with short standards that form bearings for he worm shaft, R, on which the flange pulley, O, is ro- ated, the outer bearing being a pivot, P, which receives he entire thrust of the shaft, R, thus reducing the fric- ion to a minimum. It is connected direct to the indi- ator upon the projecting arm that supports the paper rum, B, and the teeth of the worm shaft, R, mesh di- ectly into the teeth on the drum carriage. Connected vith the base piece, K, is a spring Case, D, and on the

extreme end of the worm shaft, R, is secured a clutch consisting of a collar, A, through which the clutch pin, I, fastened to the flange holding swivel collar, U, slides freely.

The **flanged pulley,** O, runs freely and independently on worm shaft, R, and has on its outside a clutch-shaped hub. To this pulley, O, is connected the actuating cord, which should encircle it a sufficient number of times to have its length, when unwound, a little more than equal the length of the stroke of the engine. The other end of the cord is secured either to the cross-head of the engine, to a standard bolted thereto, or to any moving part that has an exact similar motion and must be connected in line from the pulley, O.

Enclosed in the **spring case,** D, is a small, plain spiral steel spring which operates solely to return the pulley, O, back to its starting point, after it has been revolved in one direction by the forward movement of the engine cross-head. As this pulley, O, has an independent, rotating back-and-forth motion on the worm shaft R, the necessity of unhooking the cord when the indicator is not being operated is entirely overcome. The paper drum, B, is rotated forward by means of the pulley, O, through its worm shaft, R, engaging with the worm gear, on the paper, drum carriage, and in the opposite direction, or backward, by the action of its own retracting spring. On top of paper drum, B, is a knurled thumb piece made with a projecting pin on its under side to engage with a similar pin located in the top of the drum, and is to be used by the operator for moving the paper drum slightly forward preparatory to taking a diagram, to prevent the drum from striking against its stop on the return motion.

With the indicator is furnished for use on the reducing motion, three different sized pulleys, which are of

one-inch, two-inch and three and one-half inches diameters. These pulleys are sufficient for use in taking diagrams from engines having length strokes from six inches to four feet.

Operation.—To operate this device, first select a pulley whose diameter is about one-twelfth of the length of the engine stroke in inches. See table following.

Table of the sizes of pulleys required for use on above style indicator, for piston strokes of various lengths.

Length of Stroke.	Diameter of Pulley.	Length of Stroke.	Diameter of Pulley.
1 Foot	1 Inch	4 Feet	4 Inches
1½ Feet	1½ Inches	4½ "	4½ "
2 "	2 "	5 "	5 "
2½ "	2½ "	5½ "	5½ "
3 "	3 "	6 "	6 "
3½ "	3½ "		

To properly place this pulley upon the worm shaft R, first remove the clutch, and then slide the pulley on to the shaft, being particular that the small hole in the pulley brass disc sets over the projecting pin in the cover of the spring case D. Then replace the clutch by pushing it on to the shaft as far as it will go, and secure it there by means of the set screw.

Next, place the indicator on the engine in such a position that the side of the pulley will be parallel with the motion of the cross-head. Run out the loose end of the cord to a distance of at least 12 or 18 inches, **beyond the extreme forward travel** of the cross-head, still leaving a turn or two of the cord on the pulley unwound. While holding the cord, allow it to gradually recede and rewind itself on the pulley until its loose end has reached a point coincident with the extreme backward travel of

the cross-head. If only a slight tension of the cord exists at this point it will be sufficient, and the cord may then be attached to the selected point on the cross-head. The cord tension may always be adjusted either by winding the cord on, or unwinding it from the pulley, as the case requires, one increasing and the other decreasing the tension.

A much lighter cord can be used in proportion as the sizes of the pulleys increase.

When the cross-head, with cord connected, is at its extreme forward travel, there should be just sufficient tension on the spring enclosed in the spring case D to take up all slackness of the cord when running, without overtaxing the spring. If upon starting the engine, the cord should at first run unevenly on the pulley O, turn the indicator to one side slightly, until a perfect and uniform winding of the cord is obtained, which can always be easily secured. When pulley O is running, motion to the paper drum B is obtained by pushing in the swivel collar U, to which the clutch pin is secured.

When ready to take diagrams, after placing the paper on the drum B, it is necessary first to advance the drum away from its stop fully one-quarter inch, which can be done by turning with one hand the knurled top thumb piece. While holding drum in this position, with the other hand push in gently the swivel collar U to start the paper drum in motion. The motion of the paper drum B can, at any time, be stopped, for removing diagrams taken, and renewing the paper, by withdrawing swivel collar U, or by turning top thumb piece, the latter method being preferable. The stopping of the paper drum will not affect the motion of the pulley O, which will continue to revolve independently while the engine is in motion until the cord is disconnected.

Outside Connected Springs.—High temperatures in ngine cylinders have had an effect upon indicator contruction. The effect of high temperature in both steam nd gas engines upon the pressure springs placed inside he cylinders is very injurious and causes rapid deteriortion of the springs and consequent inaccuracy of the inicator diagram. To overcome this objection **outside** onnected springs are used.

The Tabor Outside Spring.—It will be seen in the llustration shown in Fig. 283 that the only important hange to meet these more exacting conditions was the emoval of the pressure spring from the inside of the ylinder and placing it on the outside of the indicator vhere the temperature is but very little higher than the ormal temperature of the surrounding atmosphere. This onstruction is advantageous for several reasons aside rom relieving the spring from the deteriorating effect f high temperatures. One particular advantage is that ts location outside of the cylinder makes the spring more ccessible for changing. To remove or change a spring t is unnecessary to disconnect the indicator or to handle ighly heated parts. The spring can be changed immeliately if it is desired, and it is never necessary to allow he indicator to cool in order to accomplish this.

Springs for inside and outside spring indicators difer. In ordering, it must be unmistakably stated which tyle of spring is required.

CHAPTER XXIX.

MECHANICAL REFRIGERATION.

Definition.—Refrigeration is the act of cooling or reducing the temperature of a body, and mechanical refrigeration is reducing of the temperature of a body by **artificial** means.

Methods.—This cooling process, or refrigeration, can be secured in several ways, viz.: (1) By transferring the heat of a warmer body to a colder one; the warmer body giving up its heat, and hence is cooled. Heat can only be removed from the body by bringing it in **contact** with a body colder than itself. (2) By the melting and dissolving of solids, thereby **absorbing** the heat from the surrounding bodies. (3) By the **evaporation** of those liquids which have a low boiling point; the latent heat given off by the rapid evaporation representing the degree of cold so produced. (4) By **compression** and **expansion**; the gas in resuming its original condition necessarily absorbs heat, and thus produces the refrigerating effect. This last action is based upon the well known physical law that when a gas is **compressed**, it gives out heat as its volume is **reduced.** When the gas is allowed to **expand** it **absorbs** the heat from the surrounding bodies, thus reducing their temperature, i. e., it makes them colder. In order to accomplish this refrigerating effect, the substance must have such a low **boiling point** that upon exposure to the atmosphere **rapid evaporation** takes place.

There are several substances that have a sufficiently low boiling point to be employed in the production of artificial cold, such as carbonic acid, ether, nitrous oxide, methalymene and ammonia, but the **expense** of their

duction, with the single exception of ammonia, is too
at to permit of their use for **practical** work.

The single exception to the above substances, is
iid ammonia, or anhydrous ammonia as it is known.

Anhydrous Ammonia.—This is an alkali liquid, non-
ımmable and non-explosive, which boils at a tempera-
: of 28½ degrees Fahrenheit below zero.

When we consider that the freezing point of sub-
ıces in most general use is 32 degrees Fahrenheit,
ı substances at freezing temperature would be very
m when compared to the ordinary temperature of
liquid.

he terms **heat** and **cold** are merely **relative** terms. A
perature of 32 degrees Fahrenheit is considered for
e purposes extremely cold, and yet when compared to
mperature of 461 degrees below zero, which is the
olute zero of cold so far as yet produced, it then be-
ıes such a high temperature that it could be called a
ı temperature or **warm** instead of cold.

When two bodies are brought into contact, the
mer of the two always imparts its heat to the other
l both bodies have the **same** temperature. That is,
colder body absorbs the heat of the surrounding air
bodies, the same as a sponge absorbs a liquid in
ch it is immersed.

As the heat from the surrounding bodies is absorbed
the refrigerating bodies, they become colder and the
t body becomes warmer until the temperature is
ıalized.

It is thus seen that the colder body extracts the heat
m the other body, and in turn it becomes warmer as
: other grows colder.

This is what takes place when ammonia is brought
contact with any substance, and it is by the **evapora-**

tion of ammonia that nearly all artificial ice is now made, as well as all refrigerating.

The ammonia when it is exposed to the atmosphere will evaporate and continue to absorb heat until the substance which is being cooled loses so much of its heat that it becomes as cold as the ammonia. When this point is reached, the ammonia will cease to evaporate, and will remain in a liquid state.

Pressure and Temperature.—If a gas be compressed, its volume will be reduced and its temperature raised by the heat that is squeezed out of it.

When the gas which has been compressed is released it flashes into vapor, extracting heat from the surrounding bodies and thereby lowering **their** temperature as its temperature **rises.**

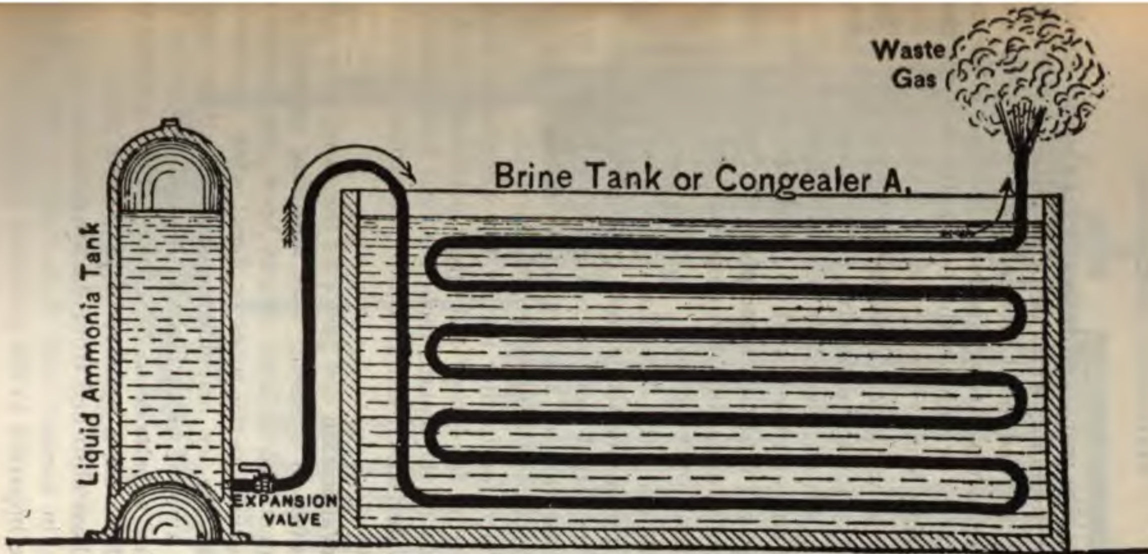
Hence, if a gas while subjected to a uniform pressure be discharged into an air-tight vessel which is being constantly cooled by water, or other substance at a lower temperature than the confined gas, the vapor or gas will condense inside the vessel and return to the liquid form, while the temperature of the cooling water is raised from the heat which it has absorbed from the gas.

The temperature of the cooling water determines the pressure to which the gas must be subjected in order to raise its point of evaporation sufficiently high to enable it to exist as a liquid, when chilled by the surface of the vessel.

All mechanical refrigeration is based upon the above principles.

Refrigerating Apparatus.—The simplest form of a refrigerating apparatus is shown in **Fig. 284.**

The rapid evaporation of the ammonia which is made to pass through a coil placed in a tank containing water or brine, reduces the temperature of the coil be-



Simplest Form of Refrigerating Apparatus.

Fig. 284.

low the freezing point, and it thereupon absorbs the heat from the surrounding water or brine in the tank or congealer as it is called, until the temperature is reduced below freezing, when it congeals and forms ice, if the tank contains water; or reduces the temperature of the brine below freezing point.

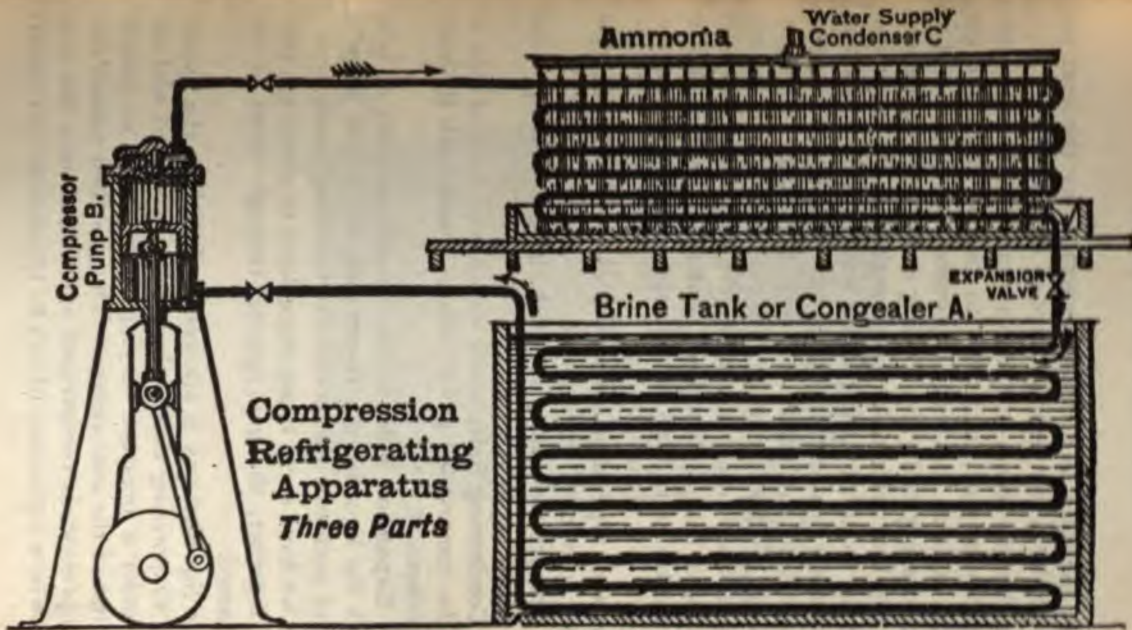
While the work performed by this apparatus is most effective, it is far **too expensive** for practical use, as the ammonia gas is all wasted, it being discharged from the end of the coil as shown in the illustration.

In Fig. 285 is shown a **complete refrigerating** apparatus, in which apparatus the ammonia gas is saved and used over and over again.

By following the direction of the arrows, it will be seen that the ammonia makes a **complete circuit** in its travel. The **actual** work of refrigeration is done by the rapid evaporation of the ammonia in the evaporation coils shown in the congealer or brine tank. The gas is then liquefied for further use by the compressor forcing it through the condenser coil under a pressure of about 175 pounds to the square inch, the heat being absorbed by cold water which flows over the condenser, as shown in the cut.

The **evaporation** coil performs the same duty as the tubes or flues in a boiler. The **steaming** capacity of a boiler depends to a large extent upon the amount of heating surface in the tubes or flues; while the freezing capacity of the ice machine depends to a large extent upon the amount of surface of this coil exposed to the air or other substance to be cooled. In a practical apparatus there are a number of such coils used.

The heat absorbed from the surrounding air, or the substance in contact with these coils, causes sufficient heat to be imparted to the ammonia liquid to boil it into



A Simple Compression Refrigerating Apparatus.

Fig. 285.

a vapor, the same as steam is generated by the heat imparted to the water from the fire in the furnace.

As the gas forms in the evaporating coils, the compressor pump is set in motion to suck or draw the gas from the coils as fast as it is formed, drawing it out of the evaporating coils and forcing it into the **condenser**, where the heat which the gas absorbed in its expansion is removed from it by the cooling water which flows over the condenser, leaving the liquid ammonia ready to again be drawn into the expansion coils for further refrigerating work. This operation is a continuous one, it only being necessary to replace at intervals the small amount of ammonia that is lost from leakage. In Fig. 287 is shown the ordinary type of compressor used for this purpose.

Cycle of Operation.—A complete cycle of operation therefore comprises three parts:

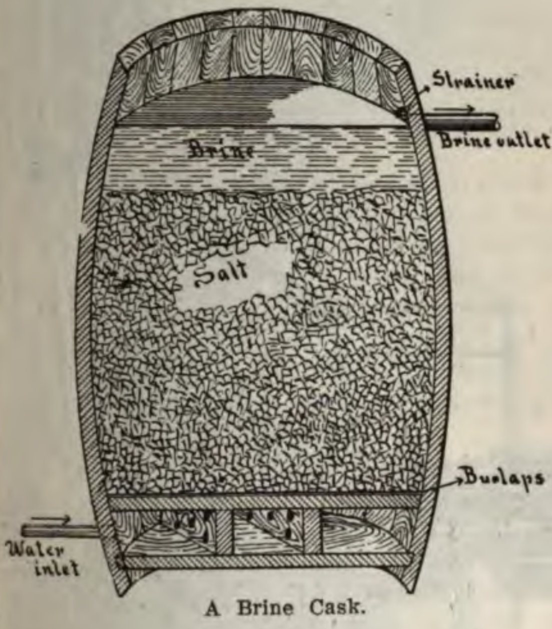
A Compression Side, in which the gas is compressed by the compressor.

A Condensing Side, which consists of coils of pipe in which the compressed gas circulates, **parts with its heat**, and liquefies.

An Expansion Side, which consists of coils of pipe in which the liquefied gas **re-expands** into a gas, **absorbs heat,** and performs the actual refrigerating work.

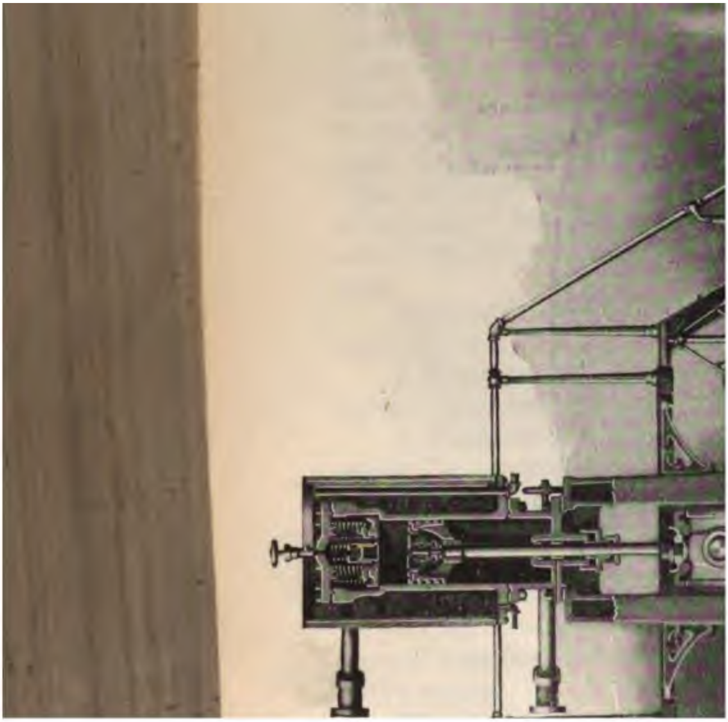
As we have seen, these three sides or parts are connected together, the gas passing through them in the order named.

The liquefied gas is allowed to flow into the expansion or evaporizing coils, where it is vaporized and expands under a pressure varying from 10 to 30 pounds above that of the atmosphere. The gas then passes into the compressor, is compressed and forced into the condenser, where a pressure of 125 to 175 pounds per square



A Brine Cask.

Fig. 286.



inch usually exists, thereby producing liquefication. The resulting liquefied gas is then allowed to flow through a stop-cock having a minute opening, called an expansion valve, which separates the compression from the expansion side of the plant.

The suction or low pressure side of the refrigerating apparatus is connected to the compressor so as to permit of this gas being drawn off as it enters the expansion coil, in this way the pressure being kept at from 10 to 30 pounds above the atmosphere.

From the description of the above apparatus it is apparent that if the expansion coils are placed in an insulated room, that the temperature of the room will be reduced or refrigerated; also if brine or wort is brought in contact with the surface of the coils they also will be reduced in temperature; and that brine so cooled can be used to refrigerate an insulated room by simply forcing it to circulate through pipes or gutters suspended in the same.

The apparatus above described can be used not only for the refrigeration of breweries, packing houses, etc., but also for the manufacture of ice, as will be hereafter explained.

Systems of Refrigeration.—To utilize the cold produced as above shown there are two systems, each of which has its advantages, viz.: (1) By pumping the **cold brine,** cooled as above explained, through a system of pipes to the apartment to be cooled, which method is called the **brine system**; and (2), By placing the evaporation coils **directly** in the apartment to be cooled, which system is called the **direct expansion system.**

Brine System.—In this system, the evaporation coils are placed in a tank which is filled with a strong brine usually made of common salt, it being selected as it will

are placed on the ceili

places in the apartment to

This process of refr reverse of heating by stea being **absorbed** in the firs **parted** in the latter.

The brine after abso ment, is finally returned again cooled by the amn lated throughout the cooli are called.

This operation of re tinuous one.

Brine Plant.—A brin pressor, (2) Condenser, (3 (5) Ammonia Expansio Pipes.

The advantages of th expansion system, are, (1 Compactness of machine same to be installed in th be under the constant c venience in circulating th

mpart but little heat between certain tempera-
ereby impeding the cooling or refrigeration. It
cause a deposit of salt in the circulating pipes,
them to clog, etc., and also producing a loss of
ducting efficiency.

e should never therefore contain more than 25
of salt, this being as much as will be held in
at zero degrees Fahrenheit.

meter.—The strength of the brine can be readily
ed by means of a **salometer,** which is simply an
nt made to float in the brine; the line to which
ndicates the percentage of salt, a reference table
ed for this purpose.

e Cask.—In Fig. 286 is given a common form of
cask, which consists simply of a barrel with a
tom, or wooden grate, about 6 or 8 inches from
om, which grating is made of small strips of
out 1 inch square, and placed not over ½ inch
This grating should be supported by two strips
6 or 7 inches wide, placed on end and nailed to
om. These boards should have several holes
ar the bottom to permit a free passage of the
The water inlet must be below the false bottom,
¼ inch pipe. A single thickness of burlap
e stretched over the bottom and tacked to the
the barrel. The outlet pipe should be about
pipe, and should be located about 5 inches below
f the barrel. Fill the barrel with salt, and turn
water. As the salt dissolves readily it is not
y to stir same. Skim off all waste matter, and
the outlet with a strainer of some kind to pre-
ps, etc., from getting into the brine.

ium Brine.—The advantage of using **calcium**
its **cleanliness.** It does not clog the pipes, and

in consequence a better conduction of heat is obtained.

Its freezing point can also be depressed several degrees **lower** than when the common salt brine is used.

The objection to its use is solely due to its comparatively **high** price.

It is prepared in a similar manner to the ordinary salt brine.

Pipes in Brine Tank.—For general refrigeration 1¼ inch pipe is used; about 150 running feet of this size pipe being allowed for each ton of refrigerating capacity during 24 hours in the brine tank.

In ice making, about 300 feet of this size pipe is used in the brine tank per ton of ice to be manufactured during the 24 hours.

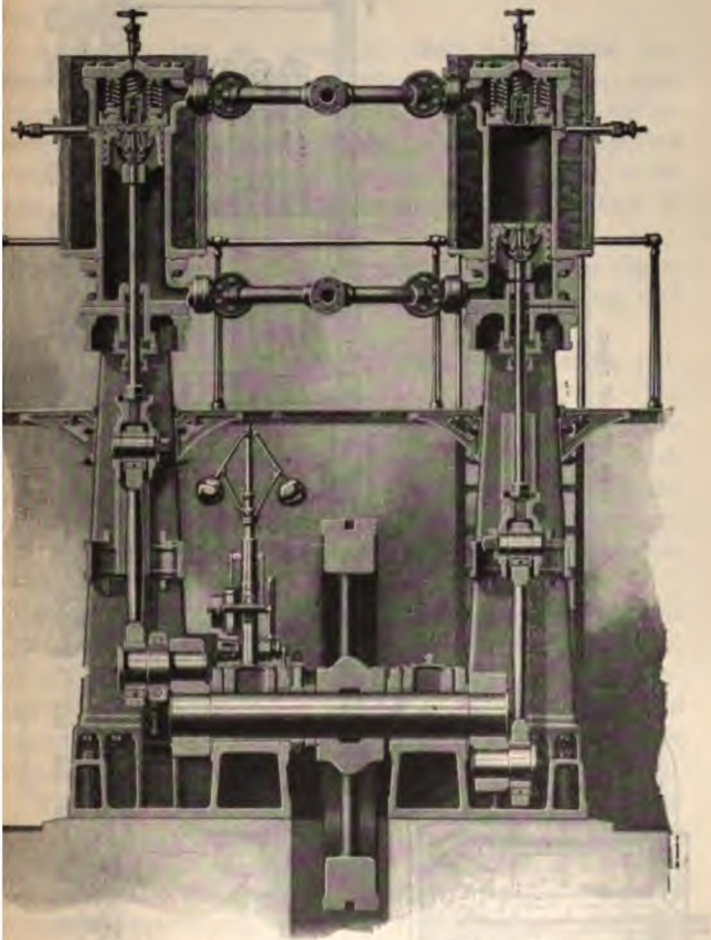
Direct Expansion System.—In this system the expansion or evaporating coils are placed directly in the apartment to be cooled, thereby entirely disposing with the use of a brine in any form.

Advantages.—The apparatus to circulate the brine, together with the power necessary to operate it, is thus saved. A **higher** efficiency is also obtained, as the difference in pressure between the delivery and return side of the compressor is much less than with the brine system.

The expense of the first cost is not only much less, but the apparatus itself is much simpler in operation.

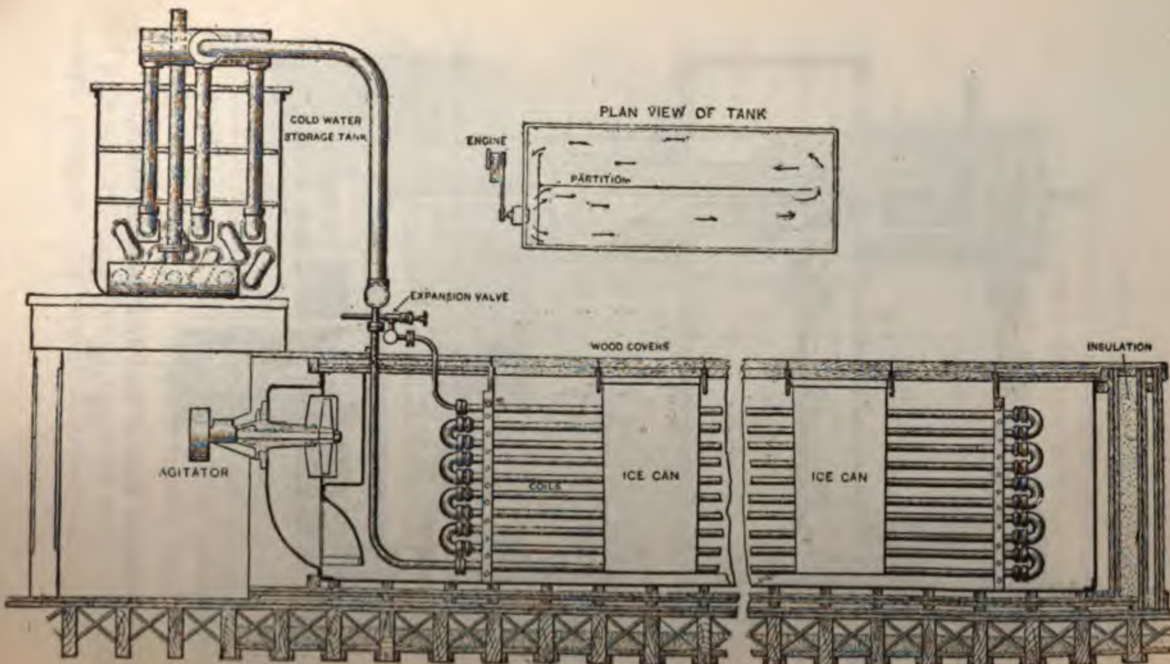
Disadvantages.—The disadvantage in the use of this system is the **leakage** in the pipes, as the gas must not only be kept under pressure, but it is extremely penetrating, and attacks the metals ordinarily used.

In order to prevent such leakage, it is necessary that all pipe and fittings be most carefully made and tested to a high pressure. All ammonia fittings are usually made



Cross Sectional View of York Refrigeration Machine.

Fig. 288.



Sectional View of Freezing Tank in Can System.

Fig. 389.

able iron, drop forgings, semi-steel or air furn.

monia has no chemical effect upon **iron**, and e all tanks, pipes or fittings made of iron, may in constant contact with ammonia, and no inaction will be apparent. The only protection e that ammonia expanding pipes require when iron, is from corrosion on the **outer** surface of

ential Parts.—A direct expansion system therey requires (1) Compresser, (2) Condensor, and iplete system of piping.

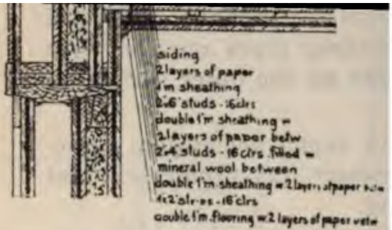
. 287 and 288 show a York refrigerating ma-

.—The size of pipe usually adopted for expans, when this system is used, is 2-inch pipe, such ng lap-welded instead of butt-welded as in the sizes. The **friction** of the gas passing through e, is also much less than when the smaller size

Making Plant.—There are two principal systems the manufacture of ice, viz.: (1) **The can system, The plate system.** In addition to these two sysre is also what is known as the **stationary cell** but as this system is rarely used, it will not be ed.

Can System.—In Fig. 289 is shown a sectional the freezing tank used in this system. This tank with salt brine, which is reduced to a temperabelow the freezing point by parallel rows of a evaporating pipes immersed in same. Between ws of evaporating pipes, sufficient space is left to be inserted.

se cans are filled with distilled water, the process ng being the same as explained where the brine



Insulation of walls built of wood

Insulation of ceilings for

system is used. The ammonia evaporating coils absorb the heat from the brine, and this in turn absorbs the heat from the water in the cans which is to be frozen.

This is the system most in use for the artificial making of ice.

The freezing tank is usually made of iron or wood. The cans are made of galvanized iron, which are covered with wooden tops. The time required to freeze the water in the cans varies from 22 to 48 hours, depending upon the thickness of the mould and the temperature. These ice moulds are generally made 100, 200, 300 and 400 pounds in size; a suitable **hoisting** apparatus being provided to remove the cans from the tanks. A **thawing** device is required to loosen the cakes of ice from the cans. Such a device usually consists of a form of a sprinkler, warm water being used. A **hot well** is often used in which the can is immersed. The cake will then easily slip out of the can, and is ready for the market.

The can is then again re-filled with fresh water, and replaced in its position in the tank, where the freezing again begins. Thus a continuous process is established, which permits of a regular output throughout the day and night. In order to get the greatest production at the least cost, ice-making plants are run day and night.

Plate System.—In this system a hollow plate, usually made of boiler iron, is immersed in a tank containing the fresh water to be frozen.

This hollow plate is filled with brine, which is kept below the freezing point by evaporating coils placed in same, as is done in the can system.

By thus keeping the plate at a sufficiently low temperature, ice will be formed on both sides of it, and in the course of time two layers of ice will be built up on the two sides of the plate. In order to remove this ice,

the cold brine is drawn from the plate, and in case the evaporating coils are inside of the plates, the circulation of ammonia in them is stopped. Tepid water is then supplied to the hollow plates, and after a short while the ice is loosened from them, and can be hoisted out of the tank by means of cranes.

In this system the ice is produced in large pieces, weighing one or more tons, and a length of time of 10 or 12 days is required to freeze it.

This system is used almost exclusively for making ice for skating rinks. The ice is made only once in a season, but the surface which is cut up by the skates is reformed every night. To prevent undue growth and thickness, the ice, from time to time is planed down by a special machine.

Efficiency of Refrigerating Machines.—The useful effect of a refrigerating machine depends upon the ratio between the heat units eliminated and the work expended in compressing and expanding.

The performance of the machine, expressed in pounds of tons of "ice-melting capacity," does not mean that the refrigerating machine would make the same amount of **actual** ice, but it means only that the cold produced is equivalent to the effect of the melting of ice at 32 degrees, to water of the same temperature.

Therefore, refrigerating machines are rated by the **effect** they produce equivalent to the melting of a corresponding amount of ice.

The melting of one pound of ice is equivalent to the absorbing of 142 units of heat, but in making ice from water, we have to remove **more** than the 142 heat units. It is first necessary to reduce the water to 32 degrees before we are ready to produce the ice. If the water is at 70 degrees this means the removal of 30 heat units. But

ice cannot be made with economy without going to a temperature **much lower** than 32 degrees. The ice when formed may have a temperature of 18 degrees, and the specific heat of ice being .5, this means the removal of 7 more heat units; we therefore have to remove 187 heat units instead of 142 units, to produce a ton of ice. Thus a 200-ton machine which would easily produce a refrigerating effect equal to the melting of 200 tons of ice, would produce only **148 tons** of actual ice, when the inevitable losses attending the use of large freezing tanks and the handling of ice is also considered.

Insulation.—Not only must the pipes running from the compressor to the condenser, and from the condenser to the expansion coils be most carefully insulated, but also the storage rooms.

By proper insulation, the heat **outside** the rooms and pipes, is prevented from penetrating or coming in contact with same, and imposing thereby additional work of refrigeration.

Were it possible to keep the **outside** heat altogether from entering the storage room, it would then be necessary to cool or refrigerate a room **but once.** But this is impossible, and it therefore becomes necessary to construct these cooling or storage rooms with the most **perfect** insulation possible, in order to avoid the employment of a large surplus of refrigerating power to take care of this negative heat.

Since a large percentage of the actual work of the refrigerating plant is required to make up for the passage of heat through the walls, floors and ceilings caused by poor insulation, therefore only **best** insulation should be used.

In Fig. 290 is shown the usual methods of insulating buildings or storage apartments.

A De La Vergne Hor
F

e De La Vergne Horizontal Ice Machine.—This own type of ice machine is shown in Fig 291, it heir horizontal motor-driven machine of 5, 10 and ype.

scription.—As in their vertical compressors, the and discharge lines are divided and so arranged ey do not have to be disconnected in order to re- ne valves. The by-pass valves, used when vari- ts of the system are to be pumped out; expansion or controlling cylinder temperatures while the being put in operation; and the main suction and ge valves are all conveniently located just above npressor cylinder within easy reach of the engi-

e arrangement of the valves peculiar to this ma- lows the same port to be utilized for both suction charge gases. This design not only reduces the e clearance, but by tempering the extremes of r wall temperatures eliminates to a great extent advantageous effects due to expansion and con- .

nile these compressors are fitted with water jack- dry compression work, the peculiar method of dis- g through ports in the bottom of the cylinder al- nis machine to easily discharge large quantities d which might accidentally enter the compressor, endangering the machine and at the same time it absolutely impossible for parts of broken to get into the cylinder. Two suction and two ge valves only are used, a point which greatly es the detecting and locating of leaks, and their ment at right angles to the cylinder makes their l as easy as that of a Corliss engine valve.

e De La Vergne System.—In Fig. 292 is shown

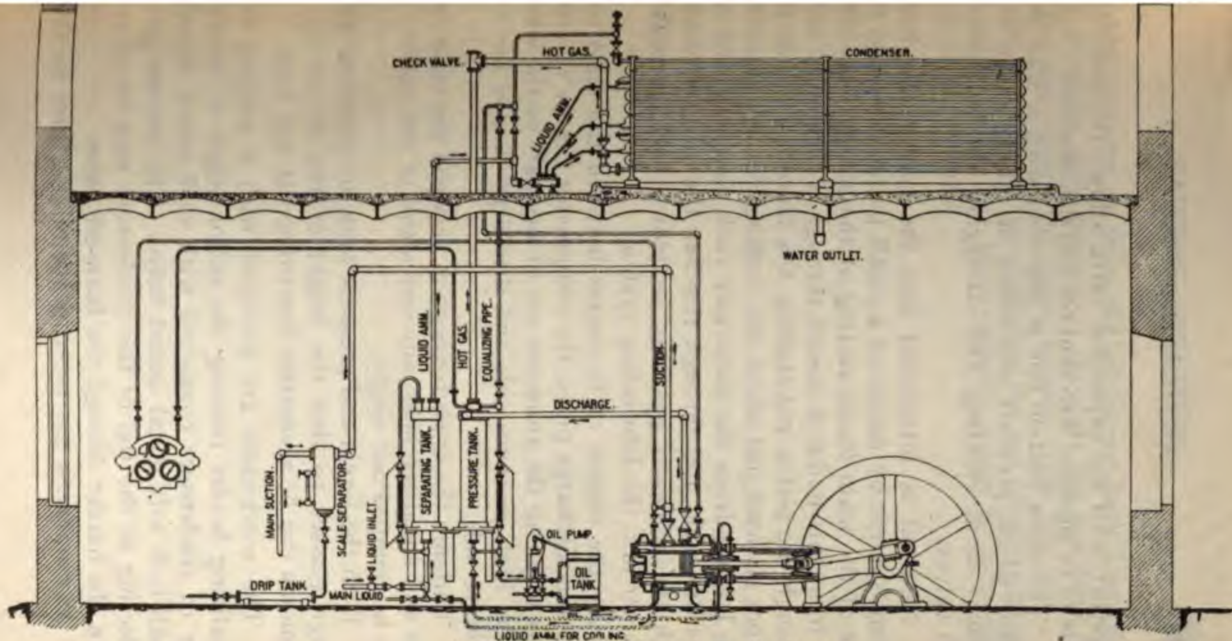
a diagrammatic general arrangement of a typical De La Vergne Refrigerating System. The hot gas discharged by the compressor passes first through a globe valve known as the **discharge valve,** at the left hand side of the cylinder and then to the **pressure tank.** Leaving the pressure tank it passes up the riser marked **hot gas line,** through a **check valve** and down a header through 2-inch pipes and soft seated globe valves of the same size, to the individual stands of atmospheric **condensers.** Leaving the condenser through the three liquid drips, the liquid ammonia from each stand passes down through a half-inch soft metal seated valve into the liquid header.

Before passing to the liquid tank, the outlet from the liquid header rises a few inches to form a **gooseneck,** which maintains a liquid seal on the condenser and prevents gas from the pressure tank from passing into the liquid line, which leads to the expansion coils. Near the part where it connects with the liquid tank, the liquid line from the condenser is provided with a pocket into which any scale or foreign matter is precipitated.

The liquid ammonia leaves the liquid tank at the bottom through the **main liquid line,** a branch from which after passing through a strainer is connected with the main suction line just above the compressor cylinder, and supplies liquid for regulating compressor temperatures while starting up, pumping out, etc.

Just outside the **main liquid valve** a small connection is made into the **main liquid line** to which ammonia drums may be connected for charging the system. Beyond this connection the main line passes to the cold storage rooms and branches out to the individual expansion valves on the various expansion coils.

The ammonia gas returning from each coil passes through a 2-inch soft metal seated globe valve, which



A Complete Refrigerating System.
Fig. 292.

together with the expansion valve allows the individual coils to be pumped out, shut off and disconnected.

The main suction line is provided with a scale separator which prevents any scales or other foreign substances from entering and damaging the compressor and valves.

New oil is introduced into the compressor lubricating system by means of a small pump shown on the side of the main frame casting of the compressor. The oil from this pump is forced through a three-way cock, through the piston rod stuffing box lantern and into the oil pot situated just above the stuffing box. The second line leading from the three-way cock connects with the pressure tank, and through this line the oil carried over with the ammonia gas may be blown back through a strainer into the lubricating system.

By the system of by-passes between the main suction and discharge pipes, the compressor can be reversed so as to pump the ammonia out of any part or the whole of the high pressure side and discharge it into the low pressure side.

Through the cross connection between the main suction and equalizer lines, any one stand of the condenser can be pumped out singly.

Both the liquid and pressure tank are provided with gauge glasses so that the height of the oil or liquid ammonia can be accurately determined at any time.

The condensers are provided with a purging and equalizing header running the entire length of the battery of condensers connected with each stand through a half-inch soft metal seated valve. The impure gases collecting in the top of the condensers may be purged from the header through the **blow-off valve.**

Any ammonia gas entering the oil pot from the stuf-

ng box lanterns or from the oil blown back from the ack pressure tank passes up through the equalizer to il pot and enters the main suction from the top. A ontinuation of this line furnishes the low pressure gauge onnection, while the high pressure gauge is connected to the pressure tank.

quantities of heavy a
arate and distinct br

The small vertic
called, with attached
ble the immense st
erected in our cities,
machinery has enabl
subways which are t
ways in the larger ci

The **steam shov**
them rests the futur

Almost all our c
in fact, the hoisting
in modern developm

Extent of Worl
work done by this
ingly low cost of sa
instances:

In excavating t
shovel handled 600 c
a day of ten hours,
about 700 cubic yar

The contract pr
varied from 20 to 50

operate these steam shovels, and similar port-
l hoisting machines, three engines are generally
ıe main engine which operates the hoisting and
ıg machinery, a smaller engine used for swing-
boom and dipper, and a third engine for thrust-
dipper handle.

size of a steam shovel is usually denoted by
city of the dipper in cubic yards and the weight
vhole machine in tons.

: following are some of the standard sizes:

ons..........	35	45	55	65	75	90
u. yds.......	1¼	1½	1¾	2	2½	3
0 hrs., tons..	¾	1	1¾	1½	2	2¼
10 hrs., gals.	1,500	2,000	2,500	3,000	4,000	4,500

price of shovels is approximately $130 per ton.

: **Hoisting Engineer.**—It is therefore seen that
ting engineer must operate and have under his
: supervision the following throttles and levers:
nging throttle, one hoisting throttle, one reverse
ıd one friction lever.

must not only be a **skilled** engineer, quick and
ıt also a most **careful** and **reliable** man, for the
many workmen would be endangered by any
ness on his part.

SIGNALS ADOPTED BY HOISTING AND POR[T]ABLE ENGINEERS.

Boom derrick with one bell or whistle.

One blow or ring, stop.
Two blows or rings, hoist the load.
Three blows or rings, lower the load.
Four blows or rings, hoist the boom.
Five blows or rings, lower the boom.
With two bells, one on load and one on boom.

Bell on Load.

One ring, stop.
Two rings, hoist.
Three rings, lower.

Bell on Boom.

One ring, stop boom.
Two rings, raise boom.
Three rings, lower boom.

Brick Hoist.

One ring, stop.
Two rings, hoist.
Three rings, load to lower.
Four rings, man coming down.

BOOM-DERRICK SIGNALS.

(1) To Raise the Load.—Arm bent at elbow a[nd] hand twisted or shaken from wrist. Speed depends u[pon] the speed with which the hand is moved.

(2) **To Raise the Boom.**—Arm bent at elbow, hand closed and thumb extending upward, the hand being moved up and down. The speed depends upon the speed with which the hand is moved.

(3) **To Stop.**—The extended arm moved horizontally from the shoulder, with the open hand.

(4) **To Lower the Boom.**—Arm extended with hand about level with waist, and a downward motion made with the hand closed, with thumb extending downward.

(5) **To Lower the Load.**—Arm extended with hand about level with waist, and a downward motion made with open hand from wrist.

(6) **To Raise Boom and Load.**—The same signals are given as in (1) and (2); one signal being given with each hand.

(7) **To Raise the Boom and Lower the Load.**—The signals are given with each hand, as in (2) and (5).

(8) **To Stop.**—Signal to stop is given by a horizontal movement of the arm.

When this movement is made with the arm with which signals are given for operating boom, it means to stop the **boom.** The same movement with the arm with which signals are given for operating the load, mean **stop** or **hold** the **load.**

RUNNER SIGNALS FOR LINE FROM NIGGER-HEAD.

(1) **To Take in Line or Go Ahead.**—Arm extended with hand about level with hips; the open hand being shaken or twisted from the wrist.

The signal-man sta
engineer when he is rea
and he gives the signal
below the level of his sl
hoisted, he raises his arn
and when the bucket is
his arm still higher and
wrist he signals to go s
ing to hoist the bucket
in the carriage. The si
ger that holds the bucke

The signal-man fac
going to travel, and sigr
arm horizontally; wher
slow, he holds his arm o
tinue to go slow, is sign
ment of the arm. A sig
his arm to his side.

The signal-man the

Facing the engineer

down **faster**, he raises his arm **higher**; when he wishes to lower slowly, he drops his arm a little; when he wishes to drop the bucket, he signals to do so by extending his arm from the shoulder with his hand raised, and by moving his hand **up and down**, the engineer lets it drop **rapidly**, so there will be enough slack to change the hook from one bucket to another.

TYPE OF STEAM SHOVEL.

Steam Shovel.—In Fig. 295 is shown the ordinary type of a steam shovel at work.

SPECIFICATIONS FOR A 55-TON STEAM SHOVEL.

Boiler, fire box type, 54"x12' 3".
Hoisting engine, double, 10"x12".
Craning engine, double, 6"x6".
Radius, 26' 0".
Clear lift, 13' 0".
Boom guys, 2½" diameter.
Boom, 24' 11¼".
Back leg, 2"x4".
Hoisting chain, 1⅛".
Dipper capacity, 2 cubic yards.
Dipper handle, 16' 6".
Length of machine, 35' 5¼".
Height from track, 13' 2¼".
Height to top of trucks, 3' 7⅛".
Distance between center of trucks, 24' 1¾".
Capacity of water tank, 1,000 gallons.
Diameter of drum, 18".

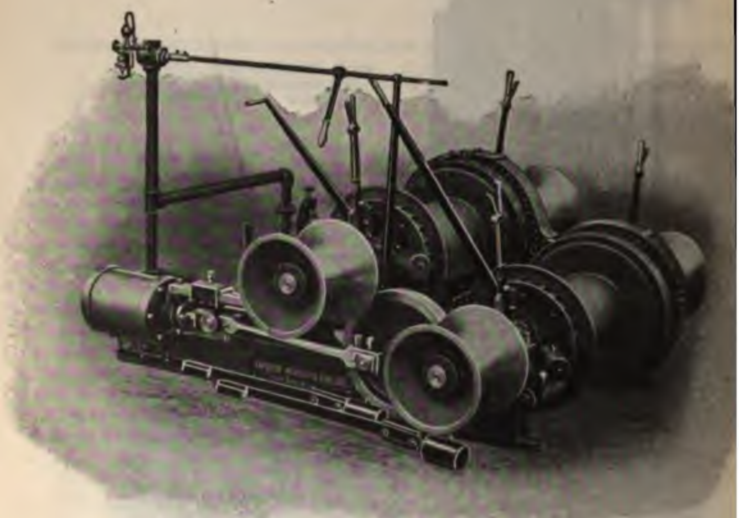
TENSILE STRENGTH OF DIFFERENT KINDS OF WIRE ROPE, COMPARED WITH MANILA ROPE

APPROXIMATE BREAKING STRESS CALCULATED IN TONS OF 2,000 POUNDS

Diameter in Inches.	Wire Transmission Rope. One hemp core surrounded by six strands seven wires each.				Wire Hoisting Rope. One hemp core surrounded by six strands of nineteen wires each.				Average Quality New Manila Rope.
	Iron.	Crucible Cast Steel.	Extra Strong Crucible Cast Steel.	Plow Steel.	Iron.	Crucible Cast Steel.	Extra Strong Crucible Cast Steel.	Plow Steel.	
2¾	....	....	....	....	114	228	266	305	26
2½	....	....	....	...	95	190	222	254	21
2¼	....	....	....	....	78	156	182	208	17
2	....	....	....	....	62	124	144	165	13½
1¾	....	....	....	....	48	96	112	128	11
1⅝	....	...	...	....	42	84	97	111	9½
1½	34	68	79	91	36	72	84	96	8
1⅜	29	58	68	78	31	62	72	82	7
1¼	24	48	56	64	25	50	58	67	6
1⅛	20	40	46	53	21	42	49	56	5
1	16	32	37	42	17	34	39	44	4
⅞	12	24	28	32	13	26	30	34	3
¾	9.3	18.6	21	24	9.7	19.4	22	25	2[illegible]
⅝	6.6	13.2	15.1	17	6.8	13.6	15.8	18	1[illegible]
9/16	5.3	10.6	12.3	14	5.5	11.0	12.7	14.5	1[illegible]
½	4.2	8.4	9.70	11	4.4	8.8	10.1	11.4	1[illegible]
7/16	3.3	6.6	7.50	8.55	3.4	6.8	7.8	8.85	[illegible]
⅜	2.4	4.8	5.58	6.35	2.5	5.0	5.78	6.55	[illegible]
5/16	1.7	3.4	3.88	4.35	1.7	3.4	4.05	4.50	[illegible]
9/32	1.4	2.8	3.22	3.65	...	....	.....	....	[illegible]
	....	....	....	....	1.2	2.4	2.70	3.00	[illegible]

The American Steel and Wire Co.
Table No. 27-(1).

A Lambert Hoisting Engine.
Fig. 293.



A Double Cylinder Friction Drum Hoisting Engine.
Fig. 294.

Hoisting Engine.—In. Fig. 293 is shown a Lambert hoisting engine, especially adapted for building erection, and extensively used by bridge builders and structural iron workers. The engine in this cut has two independent friction drums fitted with ratchets and pawls which are used for ordinary hoisting in the usual manner. It also has four winch heads, two fixed on the drum shafts and two independent winch heads, which are loose on the outward shaft, operated by an improved spiral jaw clutch, which is thrown in and out of gear by means of upright lever, as shown in the cut. These levers are provided with thumb latches and work on notch quadrants to prevent the clutch from accidentally becoming disengaged These winches are provided with ratchets and pawls for holding the load suspended while the other winches and drums are being operated.

The whole machine is designed for heavy duty. The hafts are of steel of large diameter. The winches are irge and the proper shape to do the work in a satisfactory manner. Foot brakes can be attached to both rums when specially ordered.

ABLE OF SIZES AND DIMENSIONS OF HOISTING ENGINES.

Horse Power Usually Rated.	Dimensions of Cylinders.		Dimensions of Drums.		Weight Hoisted, Single Line.	Dimensions of Boiler	
	Diam. Inches.	Stroke, Inches.	Diam. Inches.	Length Between Flanges, Inches.		Diam. Shell, Inches.	Height Shell, Inches.
14	6½	8	14	22	3500	34	84
18	6½	10	14	24	4500	36	84
25	7½	10	14	28	7000	40	90
60	10½	14	16	34	14000	52	108

Double Cylinder Double Friction Drum Hoisting ngine.—In Fig. 294 is shown a type of this engine espe-

ially adapted for bridge building, structural iron work nd erection of all classes. This engine has four im-roved independent clutch winches.

TABLE OF SIZES OF HOISTING MACHINES.

Iorse 'ower snally ated.	Dimensions of Cylinders.		Dimensions of Drums.		Weight Ho sted, Single Line, Usual Speed.
	Diam. Inches.	Stroke, Inches.	Diam. Inches.	Length Between Flanges.	
20	7	10	14	18	5000
30	8¼	10	14	24	8300
40	8½	12	16	29	10000
60	10½	14	16	32	15000

ROPER SPECIFICATIONS FOR THE CONSTRUCTION OF PARTS OF HOISTING ENGINE MACHINES.

Friction Drums.—Long experience has proven that form of friction drum is equal in durability, simplicity nd sensitive action to one where contact is maintained the pressure of a screw and prompt and sensitive re-ase is maintained by a releasing spring between the um head and the friction head. The capacity of such drum has been completely established by thousands of ich drums in use for the past twenty years. All at-mpts to secure success and leave out the recoil spring ive been failures, and the attempts to overcome this ficiency by a double bevel or V contact, finally resulted the return to the recoil spring. It is all a question of rrect angle of the conical contact surface and the diam-er of the friction head. A single faced conical bearing ill hold and release better than a double V shaped face

when the angle between the bevel face and straight face is the same as that between the two bevel faces of the double V, and to make the double V release with equal sensitiveness, it has to be blunter, while the unequal expansion caused by the heat generated by friction will act to enlarge the diameter of the metal surface, while the wooden contact surface remains the same, so that the double V surface, ultimately, in action, becomes a single gearing surface, while the single bevel surface automatically accommodates itself to changes of temperature.

The operation of the pressure screw on the drum is such that no end thrust is imparted to the drum shaft, nor to the back stand to spread the two stands.

Gearing.—Cast iron spur gears are used on account of their more lasting chilled surfaces, made from accurately cut patterns, while all the pinions are heavily shrouded and made of a high grade of cast steel.

Winch Heads.—The winch heads are of extra diameter and length, the same size and shape at each end, with a parallel surface in the middle. This design will be readily appreciated by those who have used a wet line on the common type of winch head, particularly when slacking off. The bearings on this side of the engine are double the length and the winch head comes close against the bearing, thus avoiding springing the shafts, as is frequently the case with the older designed engines.

Foot Brakes.—All engines are made so that foot brakes can be put on at any time if they are found necessary, but are only sent with engines when especially ordered. They are only recommended for long, heavy hoists, or when desired to use the engine for other purposes while the weight hangs suspended. The regular

:tion drum is all that is required for ordinary hoisting l lowering purposes.

Fly Wheels.—Fly wheels used on single cylinder en-es are of cast iron with face turned crowning and ple width of belt face to transmit full power of engine en used for pumping, sawing or other purposes.

Guard Bands.—Guard bands are used to cover the ring so as to protect the rope or prevent any other ident from obstructions getting into the teeth.

Cylinder Drain Cocks.—Cylinder drain cocks are vided for every cylinder and at both ends. They are connected to a single lever convenient for the engi-r, and are available in lowering heavy loads against :k steam pressure.

	Stan Dist. one	We	Out
$\frac{1}{4}$	[illegible]	$\frac{3}{4}$	$1\frac{5}{16}$
$\frac{5}{16}$	[illegible]	1	$1\frac{1}{2}$
$\frac{3}{8}$	[illegible]	$1\frac{1}{2}$	$1\frac{3}{4}$
$\frac{7}{16}$	[illegible]	2	$2\frac{1}{16}$
$\frac{1}{2}$	[illegible]	$2\frac{1}{2}$	$2\frac{3}{8}$
$\frac{9}{16}$	1 [illegible]	$3\frac{1}{4}$	$2\frac{5}{8}$
$\frac{5}{8}$	1 [illegible]	4	3
$\frac{11}{16}$	1 [illegible]	5	$3\frac{1}{4}$
$\frac{3}{4}$	1 [illegible]	$6\frac{1}{4}$	$3\frac{1}{2}$
$\frac{13}{16}$	$2\frac{1}{16}$	7	$3\frac{3}{4}$
$\frac{7}{8}$	$2\frac{3}{16}$	8	4
$\frac{15}{16}$	$2\frac{7}{16}$	9	$4\frac{3}{8}$
1	$2\frac{1}{2}$	10	$4\frac{5}{8}$
$1\frac{1}{16}$	$2\frac{5}{8}$	12	$4\frac{7}{8}$
$1\frac{1}{8}$	$2\frac{3}{4}$	13	$5\frac{1}{8}$
$1\frac{3}{16}$	$3\frac{1}{16}$	$14\frac{1}{2}$	$5\frac{9}{16}$
$1\frac{1}{4}$	$3\frac{1}{8}$	16	$5\frac{3}{4}$
$1\frac{5}{16}$	$3\frac{3}{8}$	$17\frac{1}{2}$	$6\frac{1}{8}$
$1\frac{3}{8}$	$3\frac{9}{16}$	19	$6\frac{7}{16}$
$1\frac{7}{16}$	$3\frac{11}{16}$	$21\frac{1}{6}$	$6\frac{11}{16}$
$1\frac{1}{2}$	$3\frac{7}{8}$	23	7
$1\frac{9}{16}$	4	25	$7\frac{3}{8}$
$1\frac{5}{8}$	$4\frac{1}{4}$	28	$7\frac{3}{4}$
$1\frac{11}{16}$	$4\frac{1}{2}$	30	$8\frac{1}{8}$
$1\frac{3}{4}$	$4\frac{3}{4}$	31	$8\frac{1}{2}$
$1\frac{13}{16}$	5	33	$8\frac{7}{8}$
$1\frac{7}{8}$	$5\frac{1}{4}$	35	$9\frac{1}{4}$
$1\frac{15}{16}$	$5\frac{1}{2}$	38	$9\frac{5}{8}$
2	$5\frac{3}{4}$	40	10
$2\frac{1}{16}$	6	43	$10\frac{3}{8}$
$2\frac{1}{8}$	$6\frac{1}{4}$	47	$10\frac{3}{4}$
$2\frac{3}{16}$	$6\frac{1}{2}$	50	$11\frac{1}{8}$
$2\frac{1}{4}$	$6\frac{3}{4}$	53	$11\frac{1}{2}$
$2\frac{3}{8}$	$6\frac{7}{8}$	$58\frac{1}{2}$	$11\frac{7}{8}$
$2\frac{1}{2}$	7	65	$12\frac{1}{4}$
$2\frac{5}{8}$	$7\frac{1}{8}$	70	$12\frac{5}{8}$
$2\frac{3}{4}$	$7\frac{1}{4}$	73	13
$2\frac{7}{8}$	$7\frac{1}{2}$	76	$13\frac{3}{8}$
3	$7\frac{3}{4}$	86	14

Pitch, Dimensions, Weigh
Steam Shovel, Dred
Table

CHAPTER XXXI.

LAWS AND REGULATIONS PROVIDING FOR THE INSPECTION OF BOILERS AND THE LICENSING OF ENGINEERS AND FIREMEN.

The following laws and regulations have been selected not only on account of the general information contained in them, but also as containing much valuable knowledge of especial interest to the student of steam engineering.

Graded License.—While a **graded** license for engineers has been adopted by many of the States, owing to the difficulty in enforcing its requirements, it has not met with universal success. The St. Louis license law which provides for only one grade of engineer's license is given as a model law, it being entirely **practical** and its requirements strictly enforced.

Licensing Firemen.—The licensing of **firemen,** but placing them **under** the engineer who is in charge of the plant, is meeting with much favor, and the ordinance of New York City providing for the licensing of firemen is therefore given in full.

UNITED STATES GOVERNMENT REGULATIONS.

For the Inspection of Boilers and the Licensing of Engineers.

Inspection of Boilers.—Sec. 4418. The local inspectors shall also inspect the boilers of all steam vessels before the same shall be used, and once at least in every year thereafter. They shall subject all boilers to the hydrostatic pressure; and shall satisfy themselves by thorough examination that the boilers are well made, of good and suitable material; that the openings for the

passage of water and steam, respectively, and all pipes and tubes exposed to heat, are of proper dimensions and free from obstruction; that the spaces between and around the flues are sufficient; that the flues are circular in form; that the fire line of the furnace is at least two inches below the prescribed minimum water line of the boilers; that the arrangement for delivering the feed water is such that the boilers can not be injured thereby; and that such boilers and machinery, and the appurtenances, may be safely employed in the service proposed in the written application, without peril to life. They shall also satisfy themselves that the safety valves are of suitable dimensions, sufficient in number, and well arranged; and that the weights of the safety valves are properly adjusted, so as to allow no greater pressure in the boilers than the amount prescribed by the inspection certificate; that there is a sufficient number of gauge cocks properly inserted, **and suitable steam gauges to indicate the pressure of steam;** and that there are reliable low-water gauges; and that the fusible metals are properly inserted so as to fuse by the heat of the furnace, whenever the water in the boilers falls below its prescribed limits; and that adequate and certain provision is made for an ample supply of water to feed the boilers at all times, whether such vessel is in motion or not, so that in high-pressure boilers the water shall not be less than four inches above the top of the flues; and that means for blowing out are provided, so as to thoroughly remove the mud and sediment from all parts of the boilers, when they are under pressure of steam. All boilers used on steam vessels and constructed of iron or steel plates, inspected under the provisions of section forty-four hundred and thirty, shall be subjected to a hydrostatic test, in the ratio of one hundred and fifty

[redacted]

to the square inch to one hundred pounds to the inch of the working steam power allowed. No ›r pipe, nor any of the connections therewith, : approved, which is made, in whole or in part, material, or is unsafe in its form, or dangerous :fective workmanship, age, use, or other cause.

ıtrol of Safety Valves.—Sec. 4419. One of the valves may, if in the opinion of the local inspec- is necessary to do so, be taken wholly from the of all persons engaged in navigating such vessel ured by the inspectors.

mping of Boiler Plates.—Sec. 4431. Every plate r-iron or steel, made for use in the construction nboat boilers, shall be distinctly and permanently l by the manufacturer thereof, and, if practicable, places that the marks shall be left visible when ıtes are worked into boilers, with the name of the :turer, the place where manufactured, and the of pounds tensile strain it will bear to the sec-]uare inch; and the inspectors shall keep a record office of the stamps upon all boiler plates and which they inspect.

ssure of Steam Allowable.—Sec. 4433. The ; steam-pressure allowable on boilers constructed s inspected as required by this title, when single- shall not produce a strain to exceed one-sixth :nsile strength of the iron or steel plates of which ilers are constructed; but where the longitudinal the cylindrical parts of such boilers are double- and the rivet holes for such boilers have been rilled instead of punched, an addition of twenty :um to the working pressure provided for single- may be allowed: Provided, that all other parts boilers shall correspond in strength to the addi-

tional allowances so made; and no split-calking shall in any case be permitted.

Rule for Determining Steam Pressure Allowed on Boilers.—Multiply one-sixth (1-6) of the lowest tensile strength found stamped on any plate in the cylindrical shell by the thickness—expressed in inches or parts of an inch—of the thinnest plate in the same cylindrical shell, and divide by the radius or half diameter—also expressed in inches—and the sum will be the pressure allowable per square inch of surface for single riveting, to which add 20 per cent for double riveting, when all the rivet holes in the shell of such boiler have been "fairly drilled" and no part of such hole has been punched.

Pressure Allowed on Bumped Heads.—Multiply the thickness of the plate by one-sixth of the tensile strength, and divide by one-half of the radius to which head is bumped, which will give the pressure per square inch of steam allowed.

Pressure Allowed Aften Ten Years' Service.—Any boiler having been in use ten years or more shall, at the first annual inspection thereafter, be drilled at points near the water line, and at bottom of shell of boiler, or such other points as the local inspectors may direct, to determine the thickness of such material at those points, and the general condition of such boiler or boilers at the time of such inspection; and the thickness of said material shall be determined thereafter at such annual inspection as the local inspector may deem necessary, and the steam pressure allowed shall be governed by such ascertained thickness and general condition of the boiler.

License of Engineer.—Sec. 4441. Whenever any person applies for authority to perform the duties of engineer of any steam vessel, the inspectors shall ex-

amine the applicant as to his knowledge of steam machinery, and his experience as an engineer, and also the proofs which he produces in support of his claim; and if, upon full consideration, they are satisfied that his character, habits of life, knowledge, and experience in the duties of an engineer are all such as to authorize the belief that he is a suitable and safe person to be intrusted with the powers and duties of such a station, they shall grant him a license, authorizing him to be employed in such duties for the term of five years, in which they shall assign him to the appropriate class of engineers; but such license shall be suspended or revoked upon satisfactory proof of negligence, unskillfulness, intemperance, or the willful violation of any provision of this title. Whenever complaint is made against any engineer holding a license authorizing him to take charge of the boilers and machinery of any steamer, that he has, through negligence or want of skill, permitted the boilers in his charge to burn or otherwise become in bad condition, or that he has not kept his engine and machinery in good working order, it shall be the duty of the inspectors, upon satisfactory proof of such negligence or want of skill, to revoke the license of such engineer and assign him to a lower grade or class of engineers, if they find him fitted therefor.

MASSACHUSETTS LAW.

To Provide for the Licensing of Engineers and Firemen.

Section 1. It shall be unlawful for any person to have charge of or to operate a steam boiler or engine in this Commonwealth, except boilers and engines upon locomotives, motor road vehicles, boilers in private residences, boilers in apartment houses of less than five flats,

boilers under the jurisdiction of the United States, boilers used for agricultural purposes exclusively, boilers of less than eight horse power, and boilers used for heating purposes exclusively which are provided with a device approved by the chief of the district police limiting the pressure carried to fifteen pounds to the square inch, unless he hold a license as hereinafter provided; and it shall be unlawful for any owner or user of any steam boiler or engine, other than those boilers or engines above excepted, to operate or cause to be operated a steam boiler or engine for a period of more than one week, unless the persons in charge and operating such boiler or engine are duly licensed.

Section 3. Any person desiring to act as engineer or fireman shall make application for a license to so act, to the examiner of engineers for the city or town in which he resides or is employed, upon blanks to be furnished by the examiner. The application must show his experience during the preceding three years or time of service. The applicant shall be given a practical examination, and if found competent and trustworthy, he shall receive within six days after the examination, a license graded according to the merits of his examination, irrespective of the grade of license for which he applies. The applicant shall have the privilege of having one person present during his examination, who shall take no part in the same, but who may take notes, if he so desires. No person shall be entitled to receive more than one examination within ninety days, except in the case of an appeal as hereinafter provided. A license shall continue in force for three years, or until the same is revoked for incompetency or untrustworthiness; and a license shall remain revoked until a new license is granted. A license, un-

s so revoked, shall at the end of said three years be
iewed by an examiner of engineers upon application
d without examination, if the application for renewal
made within six months of expiration of license. In
se a new license of different grade is issued, the old
ense must be destroyed in the presence of the exam-
er. In case of the loss of a license by fire or other
ans, a new license shall be issued in its place, without
examination, upon satisfactory proof of such loss to
examiner.

Section 4. Licenses shall be granted according to
e competency of the applicant and shall be distributed
the following classes: Engineer's licenses,—first
ss, unlimited in horse power. Second class, to have
arge of and operate any boiler or boilers and any en-
ie not exceeding one hundred and fifty horse power.
ird class, to have charge of and operate any single
iler and any engine not exceeding fifty horse power.
remen's licenses,—first to operate any boiler or boil-
s. Second, to have charge of and operate low pressure
ating boilers where the pressure carried is less than
enty-five pounds to the square inch. Any person de-
ing to have charge of or to operate any particular
am plant or type of plant, may be examined as to his
mpetency for such service and no other, and if found
mpetent and trustworthy, shall be granted a license
r such service and no other; but no person shall be
amined for a special license for a particular plant un-
s a written request for such examination, signed by
e owner or user of said plant, is filed with the appli-
tion.

Section 5. The words "have charge" in this act shall
construed to designate the person under whose super-
sion a boiler or engine is operated. The "person oper-

ascertained upon the basis
square foot of grate surfac
the basis of one and one-ha
foot of grate surface if t
purposes exclusively. The
oned upon a basis of a me
pounds per square inch o
fifty pounds for a cond
pounds for a compound e
high pressure piston.

Section 9. Any perso
of any examiner in refusin
appeal from his decision
decision, to the remaining
act as a board of appeal,
have the power to hear t
subjects of appeal. The
privilege of having one fi
ing the hearing of his app
the same. The decision o
ing examiners so acting
the chief of the district p

harge of and operate a boiler or boilers, and to have harge of and operate engines, no one of which shall exed 150 horse power, or to operate a first-class plant der the engineer in direct charge of the plant. Third ss, to have charge of and operate a boiler or boilers exceeding in the aggregate 150 horse power, and an ine not exceeding 50 horse power, or to operate a ond-class plant under the engineer in direct charge of plant. Fourth class, to have charge of and operate ting and portable engines and boilers.

Firemen's Licenses.—Extra first class, to have ge of and operate any boiler or boilers. First class, perate any boiler or boilers. Second class, to have ge of and operate any boiler or boilers where the sure does not exceed 25 pounds to the square inch, operate high pressure boilers under the engineer or nan in direct charge thereof. A person holding an a first or first-class fireman's license may operate a l-class plant under the engineer in direct charge of plant. A person holding an engineer's or fireman's nse who desires to have charge of or to operate a parlar steam plant or type of plant may, providing he s an engineer's or fireman's license, if he files with application a written request signed by the owner or of said plant for such examination, be examined as is competence for such service and no other, and if d competent and trustworthy shall be granted a nse for such service and no other. No special license ll be granted to give any person charge of a plant over horse power.

PENNSYLVANIA LAW.

To Provide for the Licensing of Engineers.

Section 1. Be it enacted, &c., That it shall be un-

pounds pressure per squa
persons are upwards of t
holds a license, as hereina
be unlawful for any owne
any steam boiler or steam
other than those excepted
be operated a steam boile
duly licensed engineer.

Section 2. All perso
form the duties of an engi
inspector of such cities, wh
as to his knowledge of ste
ence in operating the sam
in support of his claim, a
the inspector is satisfied t
habits of life, knowledge,
of an engineer, are all su
that he is a suitable and sa
the powers and duties of
him a license upon the p
authorizing him to be em
term of one year, and suc

able steam boilers and steam engines only; such
ises shall not be transferred from one grade to the
r without a re-examination, said re-examination to
onducted without cost to the licensee.

No person shall be eligible for examination for a
ise unless he furnishes proof that he has been em-
ed about a steam boiler or steam engine for a period
ot less than two years prior to the date of applica-
, which must be certified to by at least one employer
two licensed engineers.

ection 6. All engineers licensed under the provisions
his law shall assist the inspector in his examination
ny boiler under his charge, and shall point out all
cts and imperfections known to them in the boilers
achinery, and, in default thereof, the license of any
engineer or engineers, so neglecting or refraining,
l be revoked by the inspector.

Section 8. It shall be the duty of an engineer when
ssumes charge of boilers and machinery, to forth-
thoroughly examine the same, and if he finds any
thereof in bad condition, caused by neglect or in-
tion on the part of his predecessor, he shall imme-
ly report the facts to the inspector, who shall there-
investigate the matter, and if the former engineer
been culpably derelict of duty, he shall suspend or
ke his license.

Section 9. It shall be the duty of every licensed
neer when he vacates a position as engineer to notify
boiler inspector of such fact, and any failure to com-
with this provision shall be punishable by a suspen-
of the license for such period or periods as the
r inspector may determine.

Section 9. **Duties o**
duty of the Board to inspe
tles, generators or other
or transmitting steam for
pressure for heating or st
tanks, jacket kettles and
whatsoever kind, except a
as once in each and every
pressure test where such t
provided, that the hydros
shall not exceed the maxi
apparatus by more than f
careful external and inte
where hydrostatic pressu
amination of said appara
In certifying the worki
steam boiler, steam gen
same shall be determined
lowest tensile strength
shell of said steam boile
apparatus by the lowest
drical shell expressed in

ıe should be drilled in order that the exact thick-ıd condition may be ascertained, he shall report ıe to the Chief Inspector of Steam Boilers, who rve the owner or agent with a written notice to ıuse to the Chief Inspector within five days why ›iler, tank, jacket kettle, generator or reservoir not be drilled.

after the owner or agent has been heard, or at of five days, the Chief Inspector deems it neces-at the boiler, tank, jacket kettle, generator or r be drilled, then the boiler, tank, jacket kettle, ›r or reservoir may be drilled at points near the ne, and at the bottom of shell of boiler, or such ›ints in the boiler, tank, jacket kettle, generator voir as the inspecting officer may direct, and the s of said material shall be determined thereafter annual inspection as the inspecting officer may ›cessary, and the steam pressure or other pres-owed shall be governed by such ascertained s and general condition of boiler, tank, jacket enerator or reservoir. And the drilling and plug-said holes shall be done at the expense of the

boiler may be tested and rated in accordance United States Marine Inspection Law govern-ınspection of steam boilers. But no boiler, tank, ettle or jacket constructed or re-constructed of ates hereafter, where the same are required, shall y bolts of less than seven-eighths of an inch in and pitched more than seven inches apart. And onary boilers, tanks, jacket kettles or jackets a pressure of one hundred pounds or over to re inch, the construction of which requires stay ıall be equipped with hollow stay bolts. All

be carried by any one bra
the strain on braces in fla
rivets shall be considered
shells having dished head
according to the radius o

Section 12. **Duty of**
for any person to use an
tanks subject to pressure
he shall have first procure
that said apparatus may
boiler or boilers, boiler set
smoke connections, and f
size and capacity that they
be capable of being so ma
erating steam that no den
the chimney connected w

If such owner, age
boiler or tank shall fail to
tion to make any altera
such steam plant, and sh
cations for the enlargem
and shall proceed to mak
largement without a per

by or under the engineer in charge of said appar-vithout permit or report thereof.

at any time when inspecting a steam boiler, gen-or other apparatus used for generating steam for or heating puposes the Inspector of Boilers shall ıat the furnace or fire-box in which fuel is used : purpose of generating steam is so constructed or ed as to cause the emission of dense smoke from imney connected therewith he shall report to said the condition of said plant. The owner of said boiler, generator or apparatus shall have the right in such appliance or make such alterations or use 'uel as in his judgment will prevent the emission se smoke, but this shall not constitute a compliance his ordinance unless such appliance or such fuel ıctually prevent the emission of dense smoke.

rovided, boilers on locomotives or tugs, and any boiler, generator or other apparatus carrying other :ity pressure in flat buildings or apartment build-hall be subject to inspection as hereinbefore pro-

rovided, also, that any boilers for heating purposes, in which the permit specifies that not more than ›unds of steam pressure to the square inch shall ried, shall be known as "low pressure boilers."

fter the next inspection of such boilers shall have nade following the adoption of this ordinance, in-›ns thereafter shall be made once in every three But all of such low-pressure plants may be in-d at any time thereafter, and without charge, with ıce to the provisions for draft, complete combus-r degree of combustion of fuel and prevention of ission of smoke.

firemen to operate steam
the City of New York, u
operating such boiler or b
inafter provided. Such f
the supervision and direc
or engineers.

Section 2. Should a
any time operated by a
licensed fireman or engin
owner or lessee thereof
one week from such noti
ers is again found to be c
not duly licensed under t
facie evidence of a violat

Section 3. Any per
shall make application fo
boiler bureau of the poli
licensing engineers, who
blank forms of applicati
out shall be signed by
working as an engineer
shall therein certify tha
acter, and has been en
general assistant under

boiler or boilers as specified in section one of this act shall receive within six days after such examination a license as provided by this act. Such license may be revoked or suspended at any time by the police commissioner upon the proof of deficiency. Every license issued nder this act shall continue in force for one year from ate of issue unless sooner revoked as above provided. Every license issued under this act unless revoked as erein provided shall at the end of one year from date f issue thereof, be renewed by the board of examiners pon application and without further examination. Every application for renewal of license must be made within thirty days of the expiration of such license. With every license granted under this act there shall be ssued to every person obtaining such license a certificate, certified by the officers in charge of the boiler inspection bureau. Such certificate shall be placed in the boiler room of the plant operated by the holder of such license, so as to be easily read.

Section 4. No person shall be eligible to procure a license under this act unless the said person be a citizen of the United States.

Section 5. All persons operating boilers in use upon comotives or in government buildings, and those used r heating purposes carrying a pressure not exceeding n pounds to the square inch, shall be exempt from the ovisions of this act. Such license will not permit any rson other than a duly licensed engineer to take charge any boiler or boilers in the City of New York.

CITY OF PHILADELPHIA.

Inspection of Steam Boilers.

10. The inspector shall, by himself or his assistants rsonally, at least once in every year, examine each sta-

wrought-iron sheets riveted
er's name and the quality
each sheet in accordance w
United States for steambo

He shall also inspect t
with the various attachme
the boilers and their pipe

11. He shall determi
allowed to be carried on s
they are made in whole or
riveted together, and be g
in estimating the maximu
steam boilers may be wor

12. In estimating th
seams in the cylindrical s
two formulae:

Formula A. Pitch of
punched to receive the ri
centage of the strength o
pared to the strength of th

Formula B. (Area
(number of rows of rivets

That the shearing strength of a rivet in a composite int made of iron rivets and steel plates shall not be nsidered in excess of forty thousand (40,000) pounds. ıke the lowest of the percentages as found by formula ı or B) and apply that percentage as the value of the am in the following formula (C), which determines e strength of the longitudinal seams.

Formula C. (Thickness of the boiler plate, expressed parts of an inch)x(Value of the seam as obtained by ›rmula A or B)x(Ultimate strength of the iron in the ates)÷(Internal radius of the boiler in inches)x(Factor safety)=(Pressure per square inch at which the safety ılve may be set).

14. Boiler flues and furnaces of cylindrical form subıitted to external pressure, tending to cause the cylinder › collapse, when formed of wrought-iron plates united y rivets, and all the seams made with lap-joints, shall rated by the following rule:

"Eighty-nine thousand six hundred (89,600) multiıed by the square of the thickness, and this amount vided by the length, in feet multiplied by the diameter inches of the flue, equal the safe load."

N. B.—This rule is based on the assumption that circumferential seams act as braces, and reduce the supported length of the flue or furnace to the length the sections joined by the circumferential seams.

15. The area of stay-bolts and stays submitted to ain shall be measured at their least section, and oneh of the breaking strength of the iron shall be asmed as the safe working load, if the ductility test of iron does not exceed fifteen (15) per cent, but may taken at one-fourth when the ductility test shows enty (20) per cent or over. The allowable strain on y bolts or stays of unknown quality of iron shall never

head of the boiler be eq
of the boiler to which it
the head sheet must be
plates used in the shell
ing is necessary. All fl
the value of the shell wh
or tubes. Domes and m
must be made as strong
by any of the well-know
the inspector.

22. Each boiler sha
and one glass water gau
a second glass water ga
pendent connection wi
necting pipe is used fo
least nine (9) square
tions to which shall be
one-quarter (1¼) inch
must be so placed that
four (4) inches above t
of the fire box. The l
in glass gauge must b

Every safety valve shall have an arm or bearer distinctly notched and marked with five pounds or ten pounds divisions, and shall have but one "P" or ball for a weight. The weight of said "P" or ball is to be determined by the inspector, the pounds and ounces of which shall be stamped or plainly marked on the weight and on the lever, and a record of the same is to be kept in the office of the inspector; and the arm shall not have greater length than will allow the "P" to be placed so as to produce on the boiler the maximum pressure which the certificate authorizes to be carried.

Schedule A, Referred to in Section 23.

Least aggregate area of safety valve (being the least sectional area for the discharge of steam) to be placed upon all stationary boilers with natural or chimney draft.

This area may be expressed by the formula

$$A = \frac{22.5\,G}{P + 8.62}$$

in which A is area of combined safety valves in inches. G is area of grate in square feet. P is the pressure of steam in pounds per square inch to be carried in the boiler above the atmosphere.

The following table gives the results of the formula for one square foot of grate as applied to boilers used at different pressures:

Pressure Per Square Inch.

10	20	30	40	50	60	70	80	90	100	110	120
1.21	0.79	0.58	0.46	0.38	0.33	0.29	0.25	0.23	0.21		0.17

[Area corresponding to each square foot of grate.]

Example: Boiler 25 square feet of grate area and sixty pounds pressure.

For one square foot (from table) 0.33
25 square feet.

8.33 square inches.

This would call for two safety valves each, with 4.16 square inches area of 2.3-10 diameter.

26. The charges for inspection which shall be paid by the user or users of boilers in use by any single person, firm or company which may be inspected in one inspection, shall be as follows, viz.: For each and every boiler the sum of three (3) dollars, and for each and every square foot of grate surface twenty (20) cents.

CITY OF ST. LOUIS.

Inspection of Boilers and Licensing of Engineers.

Manner of Inspection.—Section 2203. The manner of inspection shall be substantially as follows: The owners of steam boilers and users shall have the option of taking the hammer test or the hydrostatic test; also of electing whether the Inspector of Boilers and Elevators or one of the Assistant Inspectors, mentioned in this chapter and employed and paid by the insurance companies, shall make such test. If the hammer test be asked for, the examination shall be thorough and searching upon every part of the boiler, both internally and externally, including all fittings and attachments. If the hydrostatic test be asked for, each boiler shall be tested by the hydraulic pressure one-fourth greater than the ordinary working steam pressure used, and the certificate of inspection herein provided shall state the maximum pressure at which any boiler may be worked. In case a defect shall be discovered in any boiler or attachment thereto, the Inspector of Boilers and Elevators shall report the same to the owner or user of said boiler or boil-

ers, and state the facts of the case in writing, giving a description of the particular locality in which each defect may be found, and whether of a dangerous character and necessitating immediate repair. If the Inspector of Boilers and Elevators shall at any time find a boiler which, in his judgment, is unsafe, after inspecting same, he shall condemn its further use. All boilers to be tested by the hydrostatic pressure shall be filled with water by the owners or users, and they shall furnish the necessary labor required to work and handle the pumps in applying the test. When leaks occur which prevent a successful test, the Inspector of Boilers and Elevators shall make a second test, upon receiving notice that all leaks have been repaired. If, upon making a second test, the boiler or boilers are still defective, he shall for each subsequent test, collect an additional inspection fee, but in no case shall he give a certificate until fully satisfied of the safety of the boiler or boilers. All certificates of inspection shall be for one year and no longer. Any owner or user of any boiler or boilers insured by any steam boiler inspection and insurance company duly authorized to transact business in the State of Missouri, shall, upon his request, have the hydrostatic test applied once annually, without extra charge, by the assistant boiler inspector of such company, as provided in this chapter.

Plans and Specifications.—Section 2236. Hereafter any manufacturer or builder of boilers, upon receiving a contract to construct a boiler to be installed within the limits of the City of St. Louis, shall notify the Inspector of Boilers and Elevators of the fact, and submit to him plans and specifications of same. All plates or sheets used in the construction of any boiler which is to be installed in any building within the City of St. Louis shall be carefully inspected, as well as the workmanship

St. Louis, shall notify the
vators of the fact, and file
fications of said elevator
showing the size and cons
ropes or cables, and all a
gether with the clearance
and the automatic locking
to the shaft. Before sai
operation, a certificate sh
in Section 2234.

License of Engineer
shall provide for regular
Boilers and Elevators sh
minutes of the proceedin
for business once in each
fications of applicants fo
jority of the members of
quorum for the transacti
shall keep a register of th
nating those found qualifi
board shall grant certific
from date thereof, to all

Boilers and Elevators shall be paid into the City easury, as provided by section 2209, but no charge ll be made for renewals. All certificates of licenses nted shall be signed by not less than two, and may signed by all the members of the Board. The Board Engineers may adopt such rules and regulations as y deem proper, not inconsistent with this Chapter l general law. A full Board of Engineers, by an nimous vote, shall have the power to revoke an engi-r's license for inebriety, dishonesty or neglect of his ies, when in charge of an engine or boiler in use, and y order the reinspection of any boiler whenever they ll deem it necessary for the public safety; but no nse shall be permanently revoked for cause without t giving the accused party an opportunity to be heard nis own defense. In Fig. 296 is shown the St. Louis m of a stationary engineer's license, as issued by the ard of Examining Engineers for that city.

Inspections.—All inspections made in the city, ether by deputy or assistant inspectors, are made sub-t to the approval of the Inspector of Boilers and Ele-ors.

Number.—In the City of St. Louis there are 2008 lers in use, operated by 1398 engineers. There are o elevators in operation, divided as follows, viz.:

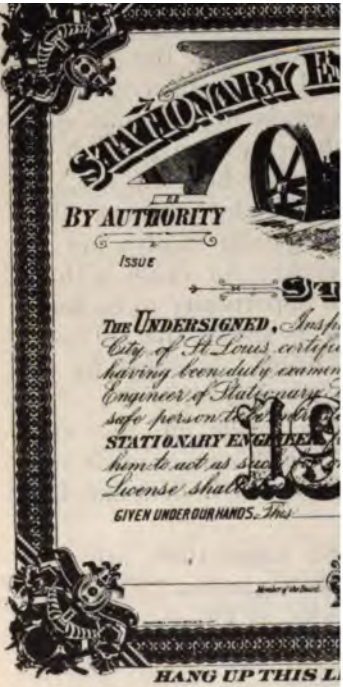
Hand Elevators, 461.

Power Freight Elevators, 1525.

Power Passenger Elevators, 554.

Requiring a total of 9332 inspections annually.

Plan for a Power Plant.—In Fig. 297 is shown a n for a power plant of the most common size, consist-of a Corliss engine, two boilers in battery, with smoke nection to outside stack on a brick base, feed water ter, pump and piping for same.


STATIONARY EN

BY AUTHORITY

ISSUE

ST

THE UNDERSIGNED, Insp
City of St. Louis certifi
having been duly examin
Engineer of Stationary
safe person to
STATIONARY ENGINEER
him to act as such
License shall

GIVEN UNDER OUR HANDS. This

Member of the Board.

HANG UP THIS L

St. Louis Station

CIRCUMFERENCE OF CIRCLES

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
1	3.1416	26	81.681	51	160.22	76	238.76	101	317.30	126	395.84
2	6.2832	27	84.823	52	163.36	77	241.90	102	320.44	127	398.98
3	9.4248	28	87.965	53	166.50	78	245.04	103	323.58	128	402.12
4	12.566	29	91.106	54	169.65	79	248.19	104	326.73	129	405.27
5	15.708	30	94.248	55	172.79	80	251.33	105	329.87	130	408.41
6	18.850	31	97.389	56	175.93	81	254.47	106	333.01	131	411.55
7	21.991	32	100.53	57	179.07	82	257.61	107	336.15	132	414.69
8	25.133	33	103.67	58	182.21	83	260.75	108	339.29	133	417.83
9	28.274	34	106.81	59	185.35	84	263.89	109	342.43	134	420.97
10	31.416	35	109.96	60	188.50	85	267.04	110	345.58	135	424.12
11	34.558	36	113.10	61	191.64	86	270.18	111	348.72	136	427.26
12	37.699	37	116.24	62	194.78	87	273.32	112	351.86	137	430.40
13	40.841	38	119.38	63	197.92	88	276.46	113	355.00	138	433.54
14	43.982	39	122.52	64	201.06	89	279.60	114	358.14	139	436.68
15	47.124	40	125.66	65	204.20	90	282.74	115	361.28	140	439.82
16	50.265	41	128.81	66	207.35	91	285.88	116	364.42	141	442.96
17	53.407	42	131.95	67	210.49	92	289.03	117	367.57	142	446.11
18	56.549	43	135.09	68	213.63	93	292.17	118	370.71	143	449.25
19	59.690	44	138.23	69	216.77	94	295.31	119	373.85	144	452.39
20	62.832	45	141.37	70	219.91	95	298.45	120	376.99	145	455.53
21	65.973	46	144.51	71	223.05	96	301.59	121	380.13	146	458.67
22	69.115	47	147.65	72	226.19	97	304.78	122	383.27	147	461.81
23	72.257	48	150.80	73	229.34	98	307.88	123	386.42	148	464.96
24	75.398	49	153.94	74	232.48	99	311.02	124	389.56	149	468.10
25	78.540	50	157.08	75	235.62	100	314.16	125	392.70	150	471.24

Table No. 28.

⅛ in.	.012	7¾ in.	47.17
¼ "	.049	8 "	50.26
⅜ "	.110	8¼ "	53.45
½ "	.196	8½ "	56.74
⅝ "	.307	8¾ "	60.1
¾ "	.442	9 "	63.61
⅞ "	.601	9¼ "	67.2
1 "	.785	9½ "	70.8
1⅛ "	.994	9¾ "	74.6
1¼ "	1.227	10 "	78.5
1⅜ "	1.484	10¼ "	82.5
1½ "	1.767	10½ "	86.5
1⅝ "	2.073	10¾ "	90.7
1¾ "	2.405	11 "	95.0
1⅞ "	2.761	11¼ "	99.4
2 "	3.14	11½ "	103.8
2¼ "	3.97	11¾ "	108.4
2½ "	4.90	12 "	113 0
2¾ "	5.93	12¼ "	117.8
3 "	7.06	12½ "	122.7
3¼ "	8.29	12¾ "	127.6
3½ "	9.62	13 "	132.7
3¾ "	11.04	13¼ "	137.8
4 "	12.56	13½ "	143.1
4¼ "	14.18	13¾ "	148.4
4½ "	15.90	14 "	153.9
4¾ "	17.72	14¼ "	159 4
5 "	19.63	14½ "	165.1
5¼ "	21.64	14¾ "	170 8
5½ "	23.75	15 "	176.7
5¾ "	25.96	15¼ "	182.6
6 "	28.27	15½ "	188.6
6¼ "	30.67	15¾ "	194.8

WEIGHTS.

Name.		No. Grams.	Metric Denominations and Values. / Equivalents in Denominations in Use. Weight of what quantity of water at max. density
Millier or tonneau	=	1,000,000	= 1 cubic meter.
Quintal	=	100,000	= 1 hectoliter.
Myriagram	=	10,000	= 10 liters.
Kilogram or Kilo	=	1,000	= 1 liter.
Hectogram	=	100	= 1 deciliter
Dekagram	=	10	= 10 cubic centimeters.
Gram	=	1	= 1 cubic centimeter
Decigram	=	.1	= .1 cubic centimeter
Centigram	=	.01	= 10 cubic millimeters.
Milligram	=	.001	= 1 cubic millimeter.

Name.		No. Grams.	Avoirdupois Weight.	
Millier or tonneau	=	1,000,000	= 2.204.6	pounds.
Quintal	=	100,000	= 220.46	pounds.
Myriagram	=	10,000	= 22.046	pounds.
Kilogram or Kilo	=	1,000	= 2.2046	pounds
Hectogram	=	100	= 3.5274	ounces
Dekagram	=	10	= 0.3527	ounce.
Gram	=	1	= 15.432	grains.
Decigram	=	.1	= 1.5432	grains.
Centigram	=	.01	= 0.1543	grain.
Milligram	=	.001	= 0.0154	grain.

MEASURES OF LENGTH.

Myriameter = 10,000 meters = 6.2137 miles.
Kilometer = 1,000 meters = 0.62137 m. or 3,280 ft. 10 in.
Hectometer = 100 meters = 328 ft. and 1 inch.
Dekameter = 10 meters = 393.7 inches.

Meter = 1 meter = 39.37 inches.
Decimeter = .1 of a meter = 3.937 inches.
Centimeter = .01 of a meter = 0.3937 inch
Millimeter = .001 of a meter = 0.0394 inch.

MEASURES OF SURFACE.

Hectare = 10,000 square meters = 2.471 acres.
Are = 100 square meters = 119.6 square yards.

Centare = 1 square meter = 1.550 square inches.

MEASURES OF CAPACITY.

Name.	No. Liters.	Cubic Measure.	Dry Measure.
Kiloliter =	1,000 =	1 cubic meter	= 1.308 cubic yards.
Hectoliter =	100 =	.1 cubic meter	= 2 bu. 3.35 pks.
Decaliter =	10 =	10 cu. decimeters	= 9.08 quarts.
Liter =	1 =	1 cu. decimeter	= 0.908 quart.
Deciliter =	.1 =	.1 cu. decimeter	= 6.1022 cu. inches.
Centiliter =	.01 =	10 cu. centimeters	= 0.6102 cu. inch.
Milliliter =	.001 =	1 cu. centimeter	= 0.061 cu. inch.

Name.	No. Liters.	Cubic Measure.	Wine Measure
Kiloliter =	1,000 =	1 cubic meter	= 264.17 gallons.
Hectoliter =	100 =	.1 cubic meter	= 26.417 gallons.
Decaliter =	10 =	10 cu. decimeters	= 2.6417 gallons.
Liter =	1 =	1 cu. decimeter	= 1.0567 quarts.
Deciliter =	.1 =	.1 cu. decimeter	= 0.845 gill.
Centiliter =	.01 =	10 cu. centimeters	= 0.388 fluid oz.
Milliliter =	.001 =	1 cu. centimeter	= 0.27 fluid oz.

The Metric System.
Table No. 30.

TABLE OF DECIMAL EQUIVALENTS

Of 8ths, 16ths, 32ds and 64ths of an Inch.

8ths.

$\frac{1}{8} = .125$

$\frac{1}{4} = .250$

$\frac{3}{8} = .375$

$\frac{1}{2} = .500$

$\frac{5}{8} = .625$

$\frac{3}{4} = .750$

$\frac{7}{8} = .875$

16ths.

$\frac{1}{16} = .0625$

$\frac{3}{16} = .1875$

$\frac{5}{16} = .3125$

$\frac{7}{16} = .4375$

$\frac{9}{16} = .5625$

$\frac{11}{16} = .6875$

$\frac{13}{16} = .8125$

$\frac{15}{16} = .9375$

32ds.

$\frac{1}{32} = .03125$

$\frac{3}{32} = .09375$

$\frac{5}{32} = .15625$

$\frac{7}{32} = .21875$

$\frac{9}{32} = .28125$

$\frac{11}{32} = .34375$

$\frac{13}{32} = .40625$

$\frac{15}{32} = .46875$

$\frac{17}{32} = .53125$

$\frac{19}{32} = .59375$

$\frac{21}{32} = .65625$

$\frac{23}{32} = .71875$

$\frac{25}{32} = .78125$

$\frac{27}{32} = .84375$

$\frac{29}{32} = .90625$

$\frac{31}{32} = .96875$

64ths.

$\frac{1}{64} = .015625$

$\frac{3}{64} = .046875$

$\frac{5}{64} = .078125$

$\frac{7}{64} = .109375$

$\frac{9}{64} = .140625$

$\frac{11}{64} = .171875$

$\frac{13}{64} = .203125$

$\frac{15}{64} = .234375$

$\frac{17}{64} = .265625$

$\frac{19}{64} = .296875$

$\frac{21}{64} = .328125$

$\frac{23}{64} = .359375$

$\frac{25}{64} = .390625$

$\frac{27}{64} = .421875$

$\frac{29}{64} = .453125$

$\frac{31}{64} = .484375$

$\frac{33}{64} = .515625$

$\frac{35}{64} = .546875$

$\frac{37}{64} = .578125$

$\frac{39}{64} = .609375$

$\frac{41}{64} = .640625$

$\frac{43}{64} = .671875$

$\frac{45}{64} = .703125$

$\frac{47}{64} = .734375$

$\frac{49}{64} = .765625$

$\frac{51}{64} = .796875$

$\frac{53}{64} = .828125$

$\frac{55}{64} = .859375$

$\frac{57}{64} = .890625$

$\frac{59}{64} = .921875$

$\frac{61}{64} = .953125$

$\frac{63}{64} = .984375$

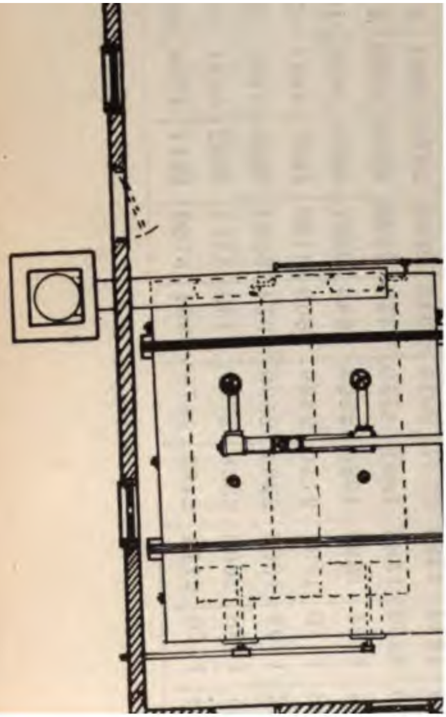
Table No. 31.

CAPACITY OF TANKS IN U. S. GALLONS.

DIAMETERS.

	5 ft.	5½ ft.	6 ft.	6½ ft.	7 ft.	7½ ft.	8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	11 ft.
5 ft.	734	888	1057	1241	1439	1652	1880	2122	2379	2768	2937	3554
5 ft. 6 in......	808	977	1163	1365	1583	1817	2068	2334	2617	3045	3231	3910
6 ft.	881	1066	1269	1489	1727	1983	2256	2546	2855	3322	3525	4265
6 ft. 6 in......	955	1155	1374	1613	1871	2148	2444	2759	3093	3599	3819	4621
7 ft.	1028	1244	1480	1737	2015	2313	2632	2971	3331	3875	4112	4976
7 ft. 6 in......	1100	1332	1586	1861	2159	2478	2820	3183	3569	4152	4406	5332
8 ft	1175	1421	1692	1986	2303	2643	3007	3395	3807	4429	4700	5687
8 ft. 6 in......	1248	1510	1797	2110	2446	2809	3196	3607	4045	4706	4993	6042
9 ft.	1322	1599	1903	2234	2590	2974	3384	3820	4283	4983	5287	6398
9 ft. 6 in......	1395	1688	2008	2358	2734	3139	3572	4032	4521	5259	5581	6753
10 ft.	1468	1776	2114	2482	2878	3304	3760	4244	4758	5536	5874	7108

Table No. 23.



CHAPTER XXXII.

ELECTRICITY.

Questions and Answers.

Q. What is **static** electricity?

A. It is electricity produced by **friction.**

Q. How is it usually produced?

A. By a **plate machine,** which is simply a circular glass plate made to revolve between rubbers, the **frictional** action of the rubbers charging the plate with electricity.

Q. What is **current** or **dynamic** electricity?

A. It is electricity in motion.

Q. How is it usually produced?

A. By means of voltaic cells, dynamos or generators.

Q. What is a voltaic cell?

A. A simple voltaic cell is formed by partially filling a glass jar with water, to which is added a little sulphuric acid, H_2So_4, together with two clean strips, one of zinc, Z, and one of copper, C.

Q. What is necessary to be done before any current will be produced?

A. It is necessary to **connect** these two plates by means of a wire or conductor in order to complete the **circuit.**

Q. In what **direction** will the current flow in the cell?

A. From the zinc to the copper strip.

Q. What are **electrodes?**

A. These are plates of metal or other substance immersed in the liquid. The zinc plate is called the **generating** electrode, and the other plate the **conducting** electrode.

Q. What are the **poles** of a battery?

A. They are the parts of the electrodes which project out of the fluid.

Q. What is an **electrolyte?**

A. It is the **exciting** fluid which acts upon the plates or electrodes placed within it, producing a current between the two plates and the wire joining them.

Q. How does the current flow in the cell?

A. From the zinc strip which is the **negative** electrode, to the copper strip, which is the **positive** electrode.

Q. Does the current always flow from the positive to the negative terminal?

A. Yes, the copper strip in the voltaic cell becoming the positive terminal.

Q. What determines the **rate** of flow of a current?

A. The **amount** of copper dissolved from one electrode and deposited on the other.

Q. What rate is taken as the **unit** of rate of flow?

A. The unvarying rate which will deposit 0.001118 of a gramme of **silver** per second, when the current is forced through a solution of nitrate of silver.

Q. What is this **unit** called?

A. An **ampere.**

Q. To what does an ampere correspond in the flow of a body of water?

A. To the **cross sectional area** of the water flowing in a pipe.

Q. What is the **volume** of **current?**

A. The number of amperes multiplied by seconds.

Q. To what is the flow of current due in a cell?

A. To the electrical **pressure,** or electromotive force generated by the decomposition of the elements forming the cell.

Q. How is electrical pressure, or electromotive force measured?

A. In **volts**, which is similar to **pounds** pressure per square inch.

Q. What other names are given to this electrical pressure?

A. Electromotive force, usually written **E. M. F.** or simply **E.**, difference of potential, tension and voltage.

Q. What causes the current to flow from a dynamo?

A. The **difference** in the electrical pressure or electromotive force generated.

Q. Is the electrical pressure generated in a dynamo in the same way as in a voltaic cell?

A. No, in a dynamo it is generated by magno-electric induction, which is the inducing of electricity by **magnetism.**

Q. What is **magneto-electric** induction?

A. It is the creation of magnetic lines of force by means of a current of electricity.

Q. What are magnetic lines of force?

A. They are invisible lines of force which pass from pole to pole of a magnet through the air or other non-magnetic substances.

Q. How is an electro-magnet made?

A. If a wire be wound around a bar of soft iron or steel, and a current sent through the wire, the bar will be found to be magnetized as long as the current flows; that is, it will possess the power of **attracting** iron or steel.

Q. Why will it attract to it pieces of iron or steel?

A. Because the lines of force always exert their power in the direction of **shortening** their travel, and the pieces of iron or steel are better conductors than the air, and will therefore **shorten** the travel of the lines of

force from one pole to the other pole.

Q. What is a solenoid?

A. It is a coil of wire which is magnetized by the passage of a current of electricity.

Q. Is it a coil alone without any core?

A. Yes, the coil alone.

Q. How is electricity induced by means of magnetism?

A. By cutting the lines of force with a conductor, such as a wire. In this simple way almost all dynamic electricity is generated.

Q. How much electrical pressure is generated by moving a wire across line of force?

A. **One volt** for each 100,000,000 lines of force cut per **second** by the wire.

Q. Give a formula for determining the electromotive force or voltage of an electrical generator?

A. Volts = lines of force × revolutions per second × conductors on the armature ÷ 100,000,000.

Q. What are these lines of force usually called?

A. The magnetic flux, and the **space** through which they pass is called the **magnetic field.**

Q. Are all magnets surrounded by a magnetic field?

A. Yes, to a more or less extent.

Q. Is there any **limit** to the number of magnetic lines of force that can be forced through a substance?

A. Yes, the iron or steel or other substances become **saturated** with the magnetism, the same as a sponge becomes saturated with water. Beyond this point the magnetic **resistance** of the iron or steel increases so rapidly that only a small increase in the magnetism can be produced.

Q. What is meant by the **permeability** of a substance?

A. It is the ability to **conduct** magnetic lines of force, or to **contain** magnetism.

Q. What is meant by **reluctance?**

A. It is the magnetic resistance of a substance.

Q. What is the **rule** for determining the **magnetic flux?**

A. The flux is equal to the magnetizing force divided by the resistance.

Q. What is Ohm's law?

A. The electrical current is equal to the electrical pressure divided by the resistance of the conductor.

Q. What is the difference between the rule for finding the magnetic flux, and for finding the **electrical** current?

A. None, except the first applies to the circuit of the **magnetic** lines of force, while the other applies to the flow of an **electrical** current.

Q. What is the purpose of an armature on a dynamo?

A. To furnish a good path for the magnetic flux passing from one pole to the other pole of the magnet.

Q. What other purpose does it serve?

A. To **cut** the lines of force forming the magnetic flux, and thereby create the electric pressure or E. M. F.

Q. Does a dynamo **create** electricity?

A. No, it only creates an electric pressure.

Q. Should the armature consist of only **one wire,** what would take place during each revolution it made in the magnetic field?

A. When the wire was moved **downward** in one direction, the electrical pressure would be sent out in one direction, but when the wire passed **upwards,** the pressure would be reversed and sent out in the other direction, causing the current to **alternate** first in one

direction and then in the other direction throughout the entire circuit.

Q. What is such a current called?

A. An **alternating** current.

Q. Are all currents when generated **alternating** currents?

A. Yes.

Q. Has a dynamo always more than **one** coil?

A. Yes, in practice the number of coils on a direct current machine ranges from sixteen to several hundred, according to the type and size of the dynamo.

Q. Can the same electrical pressure, or E. M. F., be generated by revolving the magnets around the armature so as to cause the magnetic flux to be cut by a **stationary wire** or armature?

A. Yes, it is only necessary to cut the lines of force at right angles.

Q. Upon what does the E. M. F. of an electrical generator depend?

A. Upon the **speed** of the machine, and the **size** of the magnets.

Q. Why is it necessary to put so many wires on the armature?

A. In order to obtain the required E. M. F. at a safe speed and with a moderate size **machine.**

Q. How does the **speed** effect the E. M. F.?

A. The E. M. F. furnished by each wire or armature conductor is proportioned to the **number** of magnetic lines **cut** per second by that wire or conductor, consequently the higher the **speed** of the machine the more lines of force will be cut per second.

Q. How does the size of the **magnet** effect the E. M. F. of the machine?

A. The size of the magnets determine the **number** of magnetic lines in the field, and for each 1,000,000,000

of such magnetic lines cut per second, **one volt** of E. M. F. is generated in the wire or conductor, consequently the **larger** the magnets the **greater** the E. M. F. generated.

Q. Does the speed of the machine or size of the magnets also determine the **amount** of the current sent out by the dynamo?

A. No, the **size** of the wire used on the commutator and the manner of **connecting** the windings alone determine this, the **larger** the wire, the more current it will carry without heating.

Q. Are all **armatures** made alike?

A. No, there are two general classes, the **drum** armature and the **ring** armature.

Q. What is the difference between them?

A. In the **drum** armature, the wires are wound **longitudinally,** that is lengthwise, upon the drum or core of the armature, while they are wound **around** the core of the **ring** armature.

Q. Is the armature core, that is the body upon which the wires are wound, ever made a **solid** piece?

A. No, never, but is always **laminated,** which means divided up into thin sheets or plates, which are carefully **insulated** from each other.

Q. What is the object in laminating the core, and insulating the sheets or plates?

A. To prevent the generation of **eddy** curents in the core as much as possible.

Q. What are **eddy** currents?

A. They are currents generated in masses of metal when magnetized, which cut the lines of force. They have no regular path but circulate at random.

Q. Are these eddy currents **objectionable?**

A. Yes, they are the source of constant armature loss, as they dissipate considerable energy and heat the

machine badly. By laminating the core, this loss is greatly reduced.

Q. By what other name is these currents known?

A. As **Foucault** currents, he having first recognized their existence.

Q. What is meant by the **fields** of a dynamo or generator?

A. They are the magnets from which emanate the magnetic lines of force.

Q. How are the fields constructed?

A. Wires or coils are mounted on metallic spools, which spools are made to slip over the pole pieces on the machine.

Q. What material is used in the construction of the pole pieces, and why?

A. Cast iron, cast steel and wrought iron are the principal materials used, owing to their high **permeability** or **ease** with which the **magnetic** lines of force pass through them.

Q. Are the pole pieces made of **solid** metal?

A. No, but are **laminated** to reduce the loss due to eddy currents.

Q. How are they fastened to the frame of the machine?

A. They are usually cast **integral** with the frame, but are often **bolted** to it.

Q. Where is the current in a dynamo produced?

A. In the **armature** coils.

Q. Where does the field magnets get the current to excite their coils?

A. From the armature.

Q. How is this done when the dynamo is at rest and no current is produced?

A. All iron masses **retain** a small amount of magnetism after having been once magnetized, called "re-

sidual" magnetism. This residual magnetism induces a small amount of E. M. F. in the armature and a small amount of current will therefore pass through the field coils, which in turn increases the magnetism of the field, that is, the number of lines of force cut by the armature, and this in turn increases the flow of the current in the armature and which continues to increase the "excitation" of the field until finally the machine is built up to its normal capacity.

Q. Does **all** the current sent out from the armature pass through the field coils?

A. That depends on the field windings.

Q. Why is a difference in the field windings made?

A. To adapt the machine to the different requirements of the **work** to be done.

Q. How does the requirements of the **work** differ?

A. In **arc** lighting, the **current** must be kept constant, while in **incandescent** lamp circuits and **power** circuits, the **potential** or E. M. F. must be kept constant.

Q. In order to keep the **current** constant, what must be done?

A. The whole current must be passed through the fields, and as the load varies, the E. M. F. must be made to **automatically** vary so as to keep the current constant.

Q. In order to keep the **E. M. F.** constant, what must be done?

A. Only a small part of the current must be "shunted" through the fields, and this shunted current regulated according to the load, a rheostat being used for this purpose.

Q. Is this shunted current **automatically** regulated?

A. No, the rheostat is operated by an attendant. As the load increases, the rheostat is so adjusted that the field windings take **more** current, and as the load

decreases the field windings are made to take **less** current.

Q. How does the operator know when the load increases or decreases?

A. By the use of a pilot lamp or the voltmeter which indicates the electric pressure or E. M. F.

Q. Is there any way there can be an **automatic** preservation of the E. M. F.?

A. Yes, by what is known as a **compound** winding of the field coils.

Q. How is this done?

A. By means of **two** windings in the field instead of only **one,** being a **combination** of the series and shunt windings. With these two windings, the lamps are not too bright at a low point of the load, and not too dim at the high point of the load.

Q. How do these two windings differ?

A. The **series** winding consists of a few turns of **heavy** wire, while the **shunt** winding consists of a large number of turns of **fine** wire.

Q. What is the **effect** of these two windings?

A. The **heavy** wire, or series winding, takes **all** the current that the dynamo produces, hence the more current the dynamo produces, the **stronger** it makes the fields. The fine wire, or shunt winding, takes only what the dynamo produces when there is little or no current coming from the armature. Consequently, when there is a heavy current necessary to take care of a heavy load, these two windings act in **unison**, the effect of the **total** current passing through to the series winding being augmented by the small amount of current passing through the shunt winding, which is regulated by a rheostat. We therefore see that the series winding adds as much additional magnetism to the fields as is required to compensate for the **loss** caused from

armature reaction and drop in the line. The series winding is therefore called the "**compensating**" winding. In this way the E. M. F. is **automatically** kept constant, though the current varies. A much closer regulation can also be obtained than when one winding alone is used.

Q. Have **both** alternating and direct current machines these different field windings?

A. No, only **direct current** machines.

Q. Why have not alternating machines also these different field windings?

A. Because the fields of an alternating current machine must be excited by a **direct** current, and there would be no gain in so regulating the current or E. M. F. of such machines.

Alternating current machines are known as **separately** excited machines, while direct excited machines are known as **self** exciting machines.

Q. Since all current when produced is **alternating,** how is it changed into a **direct** current?

A. By the use of a **commutator,** which device takes the place of collector rings on **alternators**, as alternating current machines are called.

Q. How is a commutator constructed?

A. Instead of being a **solid** metal ring, it is made up of segments, each segment being insulated from the other. In this way the current is made to flow always in the same direction throughout the external circuit.

Q. How does the commutator do this?

A. When the E. M. F. is at zero, both brushes rest against both segments, but when the E. M. F. increases or decreases, the positive brush rests against one segment and the negative brush against the other. When the E. M. F. again becomes zero, it again rests against both brushes. As the E. M. F. again increases, but in

an **opposite** direction, the location of the two segments change, the positive brush always receiving the outgoing current and the minus brush the incoming current. In this way the current is always sent out in only one direction.

Q. Into what three classes are all direct current machines therefore divided?

A. Into (1) series wound; (2) shunt wound; (3) compound wound machines, depending upon the winding of the field magnets, and how these windings are **connected** to the **armature.**

Q. How is the field winding connected on a **series** machine?

A. To one brush, and to the external circuit.

Q. How is the field windings connected on a shunt machine?

A. Between the brushes.

Q. How are the two field windings connected on **a compound** machine?

A. One winding is connected in **series**, and the other winding in **parallel** with the armature and external circuit.

Q. What do you mean by being connected in **series?**

A. The positive and negative terminals being connected together, the same as two horses in **tandem**, that is, one in front of the other.

Q. What do you mean by in **parallel** or **multiple?**

A. All the positive terminals being connected together and the negative terminals together, the same as two horses **abreast**, that is, side by side.

Q. What is meant by **short shunt** and a **"long shunt"** on a compound machine?

A. A **short** shunt is when the shunt coils are connected in shunt between the brushes, and a **long shunt**

when the shunt includes **both** the armature circuit, that is, the circuit from brush to brush, and also the **series** coils.

Q. What is the **effect** of connecting cells or dynamos in **series?**

A. It increases the **electrical** pressure or E. M. F. or voltage, the current remaining the same.

Q. What is the effect of connecting them in **parallel** or **multiple** arc?

A. It increases the **current** or amperage, the E. M. F. remaining the same.

Q. What is an **equalizer?**

A. It is a connection made between electrical machines for **equalizing** the electrical pressure over a system.

Q. How is the equalizer **connected** between two or more compound wound dynamos operated in parallel?

A. Into the **series** coil and **positive** brush terminal on one machine, over to the **series** coil and **positive** brush terminal on the other machine.

Q. How is it connected to the switch board?

A. To the **middle** blade of a three blade switch.

Q. What are **bus-bars?**

A. They are insulated copper bars to which the different terminals of electrical machines are connected for convenience, instead of connecting the terminals of one machine to the terminals of the other. All the positive terminals are connected to the positive bus-bars, all the negative terminals being connected to the negative bus-bars. When an equalizer is used, it is connected to a **third** bus-bar, usually placed between these two bars.

Q. Will compound machines run satisfactorily together in parallel if their series coils are **not** connected together by an equalizer?

A. No, for should the pressure at the te of one machine fall below that of the other, it immediately take a smaller proportion of the lo consequently the current in the field coils woul once reduced. This process would go on until the machine would cease to supply current, a current from the other machine flowing in the fie in a reverse direction, would **motor** the machine, it in an opposite direction to which it previously a dynamo.

By using an **equalizer,** the whole of the generated by the plant is divided among the seri of the machines equally, thus maintaining the stant and obviating all danger of reversal of **pola**

Q. With what other machines is an equaliz nection used?

A. In coupling **series** dynamos in parallel.

Q. How is a new machine switched into with one **running?**

A. The voltage at the new machine must b up to be equal, or nearly equal, to that of t running before closing the switch.

Q. How is a dynamo **cut out** of a circuit?

A. It is first necessary to **reduce** the load to amperes, either by slowing down the engine, cutting resistance into the shunt circuit by me the rheostat or hand regulator. Not until then the switch be **opened.**

Q. Is there any difference between the ar winding of an alternator and a direct current mac

A. No, but the **grouping** of the windings ferent.

Q. Does the E. M. F. rise and fall **twice** i revolution of the armature for each pole?

A. Yes, in a bi-polar machine, it rises ar

time a coil passes a pole, or twice for each pair of

). What is a **cycle?**

. A cycle represents the current's strength, or E. ., during each **complete** revolution of a single coil ipolar field, i. e., a field having **two** poles.

). What is an **alternation?**

. An alternation represents the change in a cur-luring **one-half** of each revolution of the coil, and **one** cycle is composed of **two** alternations.

). What is **frequency?**

. The **number** of cycles occurring **per second** is nated as the frequency.

). How is the frequency obtained?

. Multiply the number of **revolutions** per second e number of **pair** of poles.

). How are alternators **classified?**

. With respect to the character of the current levelop, viz., single phase, two phase, three phase, hase or multiphase machines.

). Upon what does the character of the current de-ed depend?

. Entirely upon the **armature** winding.

). What is the difference between the armature ng of a single, two and three phase machine?

. With a **single** phase machine only about **one-**f the surface of the armature is wound. Should ditional winding be placed on the armature in the left vacant, then **two** separate and distinct currents e supplied over the same circuit at the same time, e machine then becomes a **two phase** alternator.

hould still another winding be placed upon the ire between the above two coils, generating a max-E. M. F. when the other coils are not cutting the

lines of force, then it becomes a **three** phase alternator.

Q. How much do the currents delivered by a two and three phase machine differ in phase?

A. By 90 degrees, in a **two** phase machine, while those obtained from a three phase machine differ by 120 degrees.

Q. How are the two sets of coils placed on a two phase machine?

A. They must be so placed that one set is in the position of maximum activity, that is, under the center of the poles at the instant when the coils of the other set are **between** the poles, hence, in the zero position.

Q. In a two phase alternator, when the circuits are independent, how many external wires and collector rings must be used?

A. **Four** external wires and **four collector** rings.

Q. In a **three** phase alternator, when the windings are all independent of each other, how many external wires and collector rings must be used?

A. **Six** wires and **four** collector rings, though only **three collector** rings are generally used, with **four** external wires.

Q. Why are alternators always made **multipolar?**

A. So that the armature will not have to be run at a dangerous speed in order to obtain a sufficiently high frequency.

Q. How fast would a **bipolar** machine have to be run to obtain a frequency of 45 cycles per second, which is the least frequency on which incandescent lamps can be satisfactorily operated?

A. At a speed of 2700 revolutions per minute, which would be impracticable.

Q. How fast would an alternator having 10 pair of poles have to be run to have a frequency of 45 cycles per second?

A. 270 revolutions per minute.

Q. Are alternators made with stationary armatures and revolving field magnets?

A. Yes, the field magnet is a wheel with the poles projecting internally, and which is revolved inside of the armature.

Q. What other type of alternator is there?

A. The inductor type.

Q. What is the stator of a machine?

A. The stationary shell and poles.

Q. What is the rotor?

A. It is the revolving part.

Q. What is meant by self induction?

A. They are induced lines of force created by passing an alternating current through a circuit. These lines of force form loops or circles around the wire, expanding into larger and larger circles as the exciting current increases in strength, until the current finally reaches maximum. When the exciting current begins to decrease in strength, the circles decrease in size until they finally vanish when the exciting current is zero. As the current alternates throughout the circuit, each alternation produces these circles, which expand in and out around the wire as the current alternates back and forth.

Q. Are these induced currents or circles produced by the flow of a direct current.

A. No, only from alternating currents.

Q. Is this property of self induction from alternating currents of much value?

A. Yes, for it permits the transmission of large power to a great distance safely and economically.

Q. Has this self induction any objectionable features?

A. Yes, the E. M. F. generated by the expansion

and contraction of these circles or lines of force, works in opposition to the E. M. F. of the dynamo, and retards the flow of the current.

Q. What is this reactive E. M. F. called?

A. The inductive E. M. F., or the inductance of the coil.

Q. Does not this inductance increase the apparent resistance, and therefore require a greater E. M. F. at the terminals of the circuit than would be the case with a non-inductive circuit?

A. Yes.

Q. What is this additional resistance of the circuit called?

A. The reactance.

Q. What is the impendance?

A. It is the combined effect of the reactance and the ohmic resistance.

Q. What is necessary, therefore, to find the true or real value of an alternating current?

A. The applied E. M. F. must be divided by the impendance of the circuit?

Q. Why does an alternating current, and not a direct current permit the transmission of large power great distances?

A. By the use of a transformer which depends upon induction.

Q. What is a transformer, and how does it act?

A. We have seen that when an alternating current is used in one wire, it induces a current in an adjacent wire, this induction taking place only during the period of an increase or decrease in the intensity of the current. A transformer is simply an iron core of thin sheets on which are wound two sets of coils, called the primary and secondary windings.

A current of high potential sent through the primary coils **induces** a current of less potential in the **secondary coil.**

Q. Does this change the E. M. F.?

A. The original, or primary E. M. F. is not changed, but the magnetic lines created by the primary current induces a lower E. M. F. in the secondary windings.

Q. Why is the secondary E M. F. **lower** than the primary E. M. F.?

A. Because there are **fewer** turns of wire in the secondary than the primary winding.

Q. What determines the **proportion** of E. M. F.?

A. The product of the number of wires, the flux and frequency. As the frequency and flux are the same for both windings, the difference in the number of wires in the secondary winding alone determines whether the E. M. F. will be higher or lower than the E. M. F. of the secondary winding.

Q. Then to increase the primary E. M. F. what is necessary?

A. Place a **larger** number of turns of wire on the secondary winding than on the primary winding.

Q. Is the ratio of the primary to secondary E. M. F. then the same as the ratio of the primary to the secondary **turns** of wire?

A. Yes, just the same.

Q. If the primary E. M. F. was 1040 and 2080 volts, what would be the secondary E. M. F.?

A. 52 and 104 volts.

Q. What ratio would that be?

A. 20 to 1, i. e., the primary winding would have 20 times more winding than the secondary.

Q. What determines the **maximum** amount of current a transformer can stand?

A. The **resistance** of the winding and the effective area of the **radiating surface,** as the larger the size of the winding and the greater the radiating surface, the greater the amount of current that can be passed through the transformer without excessively heating it.

Q. What area of wire is usually allowed per ampere of current?

A. 1500 circular mils per ampere.

Q. What rise of temperature is allowed?

A. About 90 degrees Fahr.

Q. How is overloading of a transformer prevented?

A. By use of **fuses** in both primary and secondary circuits.

Q. How are transformers **connected** to the circuits?

A. The primary coils are usually connected **permanently** in series, while the secondary coils are so arranged that they may be connected either in series or parallel, but usually in parallel. The secondary terminals of a transformer may be considered the same as the terminals of a dynamo.

Q. What is the result of connecting the secondary coils in **series?**

A. It gives **twice** as great E. M. F. as when in parallel.

Q. Does this also increase the **output** in watts of the transformer?

A. No, it remains the same.

Q. Can transformers be worked **together,** like dynamos?

A. Yes, but it is not economical.

Q. What is the difference between a **step-up** and a **step-down** transformer?

A. The first **lowers** the voltage, while the second **raises** it.

Q. How can an ordinary step-down transformer be changed into a **step-up** transformer?

A. Simply connect the **secondary** winding to a 50 or 110 volt circuit, and the primary winding to another working circuit. This would step the voltage up from 50 or 110 volts to 1000 or 2200 volts.

Q. What is the advantage of using such **high** voltages in transmission?

A. The **higher** the E. M. F. the **smaller** the line loss, because the current or amperage can then be less. To reduce this loss the wire would have to be **heavier,** which would greatly increase the expense.

Q. Cannot high potential currents be generated on **direct** current machines?

A. Yes, but above 3000 volts the construction of the commutator becomes too expensive, and it is also extremely difficult to obtain **smooth** commutation at such a high potential.

Q. Is there any positive and negative terminals to an alternating current apparatus?

A. No, because the **polarity** changes several thousand times a minute.

Q. What is **polarity?**

A. It is the possession of poles of opposite properties. These poles determine the **direction** of the flux, i. e., the magnetic lines of force, which determines the polarity.

Q. Can two machines be worked together with **unlike polarity?**

A. No, their polarity must be the **same.**

Q. What is the simplest way to change the polarity of a machine?

A. **Raise** the brushes and throw in the current from the other **machine.** The flow of the current through the

fields makes the polarity of the two machines the same.

Q. What is the difference betwen a dynamo and a motor?

A. Practically there is none.

Q. Can a motor be used as a dynamo?

A. Yes, or vice versa.

Q. What causes the armature of a motor to revolve.

A. The outside current which partly magnetizes the field magnet, the remainder of the current magnetizing the armature, the two magnetic fields thus set up **attract** each other thus revolving the armature.

Q. Why do the magnetic fields **attract** each other?

A. Owing to the poles being **unlike,** i. e., the north pole will attract the south pole, drawing them opposite each other; and the south pole and the north pole will at the same time attract each other also drawing them to each other.

Q. Now, when the **unlike** poles are opposite each other, will not the armature come to rest?

A. Yes, were it not for the **commutator.**

Q. What does it do?

A. It **reverses** the current at the instant the **unlike** poles are opposite each other, so that the north pole of the armature becomes the south pole, and the south pole the north pole, which make two **like** poles opposite each other, i. e., the two south poles are opposite, and the two north poles also opposite each other, and as **like** poles **repel** each other, the armature is kept moving by this **repulsion** until they enter unlike magnetic fields when they are again **attracted** to each other, and in this way the armature is revolved.

Q. A motor could **not** run then without a commutator?

A. No, no more than an engine could run without a **valve** to reverse the steam against the piston at the end of its stroke. Without a valve the engine would stop on a dead center, and without a commutator the motor would stop when the magnetic axis of the commutator coincided with that of the field magnet poles, this being the **dead center** of the motor.

Q. What determines the **speed** of a motor?

A. The strength of the field, the number of armature wires and the resistance of the armature circuit.

Q. What is meant by the **armature** resistance?

A. The armature wires generate an E. M. F. when they cut the magnetic lines of the field precisely as in a dynamo. This E. M. F. is **opposed** in direction to the line E. M. F., i. e., the outside E. M. F. used to operate the motor. The result is to keep the E. M. F. down, and this reduces the amount of current, which in turn reduces the **speed** of the motor.

Q. What is it that prevents a motor from **running away** when the load is suddenly taken off of it?

A. The E. M. F. generated by the armature.

Q. Is the motor E. M. F. always equal to the E. M. F. of the line, **minus** the armáture E. M. F. i. e., the volts used up by resistance?

A. Yes.

Q. How is the **speed** of a motor **regulated?**

A. In two ways. The line E. M. F. can be cut down by putting resistance in **series** with the armature. This **decreases** the speed, as more of the line E. M. F. is used up in forcing the current through the armature resistance. The speed can also be regulated by varying the strength of the field magnets, as this varies the **back E. F. M.** of the motor.

Q. What is the effect of **strengthening** the field?

A. It **reduces** the speed of the motor.

Q. What effect has **reducing** the strength of the field?

A. It **increases** the speed of the motor.

Q. How is the speed most generally regulated?

A. By means of a **rheostat,** in series with the armature.

Q. Is a "starting box" or rheostat the same, and how is it operated?

A. Yes, the same. Its resistance coils are in series with the armature. As the motor gains speed, they are **cut out** of the armature circuit.

Q. On starting is **all** the resistance cut in the starting box?

A. Yes, and **reduced** as the motor gains speed.

Q. Should the current exceed a certain strength what will happen?

A. A magnet will **automatically** open the circuit.

Q. When the current **ceases** what takes place?

A. A magnet releases the regulating lever on the starting box, and it is pulled back to the starting point by a spring, thus **automatically** throwing in all the resistance as required when again starting.

Q. Why is the **release** magnet connected in the field circuit?

A. To protect the motor not only in the event of trouble in the line current, but also any interruption of the current through the field circuit.

Q. Have all starting boxes both the "no current" and "overload" release?

A. No, many of them have only the "no current" release. Both safety devices should always be used.

Q. Do **direct current** motors have series, shunt and compound filed windings the same as dynamos?

A. Yes, and for the same purposes.

Q. Is the speed of constant-potential motors constant?

A. Almost constant. The speed would be constant if there were no **armature resistance.**

Q. Why do some motors have **compound** filed windings?

A. In order to maintain a **very even** speed.

Q. How is the series winding connected on such motors?

A. So as to **demagnetize** the field.

Q. How is a motor **reversed?**

A. By changing the connections between the brushes and the terminals, leaving the field connections unchanged.

Q. Into what two general clases are **alternating** current motors divided?

A. Into **synchronous** and **induction** motors.

Q. How are these two classes further subdivided?

A. Into **single phase** and **poly phase** motors.

Q. What is the **difference** betwen synchronous and induction motors?

A. There are **two** principal distinctions. A **synchronous** motor has its field excited from a **direct** current source, while its armature takes current from an **alternating** current line. An **induction** motor, on the contrary, has its field supplied from an **alternating** current circuit, but its armature **is not connected to any source of supply,** the currents in it being **induced.**

Q. Which of these types of a motor are exactly similar to an alternator?

A. The synchronous motor.

Q. Are the two **interchangeable?**

A. Yes, the same as in the case of **direct current** dynamos and motors.

Q. Must the **fields** of a synchronous motor be **separately excited,** like an alternator?

A. Yes.

Q. What is the **objection** to alternating current motors?

A. The difficulty in starting up under load.

Q. How are synchronous motors started?

A. By use of a small **induction** motor, of about 1-10 capacity of the larger motor.

Q. How are **induction** motors usually started?

A. By means of an autotransformer or compensator, which reduces the heavy starting current. After the motor is up to speed, the compensator is cut out and the motor then connected directly to the line current.

Q. What determines the **difference** in the **phase** of motors?

A. The division of the **field** or stator coils into one, two or three **groups.**

Q. What then is the difference between a two phase and a three phase motor?

A. The field coils of a **three** phase motor are divided into **three** equal groups instead of only two groups, as in a two phase motor.

Q. Does the arrangement of the **field** coils of such motors correspond with the arrangement of the **armature** coils of **alternators?**

A. Yes, a one, two or three phase alternator, can be used **interchangeably** as a one, two or three phase synchronous motor as the case may be, by simply changing connections so as to supply the **armature** with the same kind of current.

Q. What is a **rotary converter?**

A. It is a direct current machine provided with ollector rings and brushes the same as an alternator, n addition to the usual commutator and brushes of a irect current machine.

Q. What is its **purpose?**

A. It is used to **change** an alternating current into a direct current, or a direct current into an alternating current, but usually to convert an alternating current into a direct current.

Q. How is it done?

A. An alternating current is supplied to the armature through the collector rings, and the machine runs as a synchronous motor, and the field magnet is **excited** from the brushes on the commutator which deliver a **direct** current.

Q. How is a direct current changed into an alternating current?

A. By supplying the machine with a direct current at proper voltage, it is made to run as a **direct current motor,** and it will deliver single phase alternating currents through the collector rings.

CHAPTER XXXIII.

THE STEAM TURBINE.

Principle.—The principle upon which the steam turbine acts is the **simplest** employed in any form of prime mover. In fact, owing to its extreme **simplicity,** the turbine was known 120 years before the Christian era, about which year **Heron** of Alexandria constructed what he called his whirling **Eolipile.** While it was a most crude device, it embodied all the fundamental principles of the **reaction** turbine of the present day.

As seen from Fig. 198, the eolipile consisted of a hollow sphere mounted on trunnions, one of which was made hollow for admission of steam. The sphere was rotated by the **reaction** of the steam flowing from two diametrically opposite nozzles with bent ends.

While no **practical** work was accomplished by this turbine, it was the **first known steam engine.**

Not until the year 1629 was there any further effort to produce a practical steam turbine. In that year **Branca** published in Rome a description of his **impulse** wheel or turbine. As seen from Fig. 299, a blast of steam was made to **imping** against the flat blades of a large wheel which was connected by cog wheels with a crude stamping mill. The **impulse** or momentum of the steam upon the blades was sufficient even in this crude device to perform **useful** work.

While the **mechanical** operation of these two devices was extremely simple, the **thermodynamic** laws which entered into their construction were wholly misunderstood.

It was not until the year 1883, that the **principles** discovered by Branca, were put into successful operation.

In that year **Gustaf De Laval,** a Swedish scientist, pro-

Hero's Steam Turbine.

Fig. 298.

Branca's Steam Turbine.

Fig. 299.

duced the first **practical** steam turbine, in which turbine those principles discovered by Branca were successfully applied.

A sectional view of the **De Laval turbine** is shown in Fig. 301. It consists of a simple turbine wheel carrying one row of buckets into which the steam is discharged in jets at their **highest possible velocity.** The extremely high velocity is obtained by using **divergent** nozzles, that is, nozzles tapered so as to **increase** their cross-sectional area toward the outlet end of the nozzle, thus permitting the steam to be **fully expanded** before leaving the nozzle, thereby giving it the highest possible velocity.

In consequence of this high velocity, the whole available **energy** of the steam is transferred into **kinetic** energy.

It was owing to not understanding **how** to utilize the energy of steam, that the Branca turbine was a failure.

To understand the steam turbine it is **first** necessary to fully understand the properties of a **steam jet,** which requires some little knowledge of thermodynamics. By **thermodynamics** is meant that branch of the theory of heat that treats of the relations betwen **heat** and **mechanical work.**

The **mechanical** construction of any steam turbine is in itself most **simple,** but the laws governing the flow of steam through nozzles, have only **recently** been fully determined.

Steam Jets.—The **fundamental** principle in any economical steam motor, whether turbine or piston engine, is the utilization of the **expansive** force of the steam. While this expansive force was recognized by James Watt as early as 1782, in which year he was granted a

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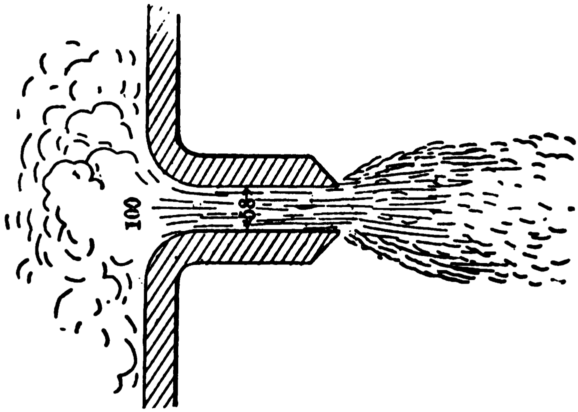
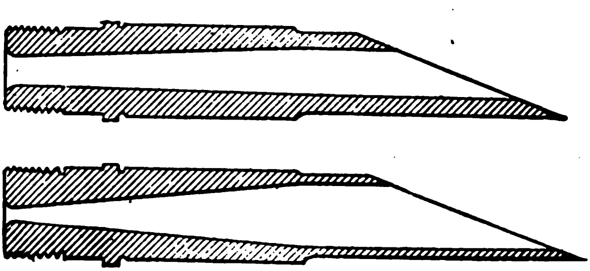


Parallel Nozzle, showing Lateral Expansion of the Steam.

Fig. 300—(1).



Diverging Nozzles.

Fig. 300—(2).

patent for its utilization in the reciprocating engine, it applied only to the **static** force of the steam expanding behind a piston, and not to the **kinetic** energy as employed in the steam turbine.

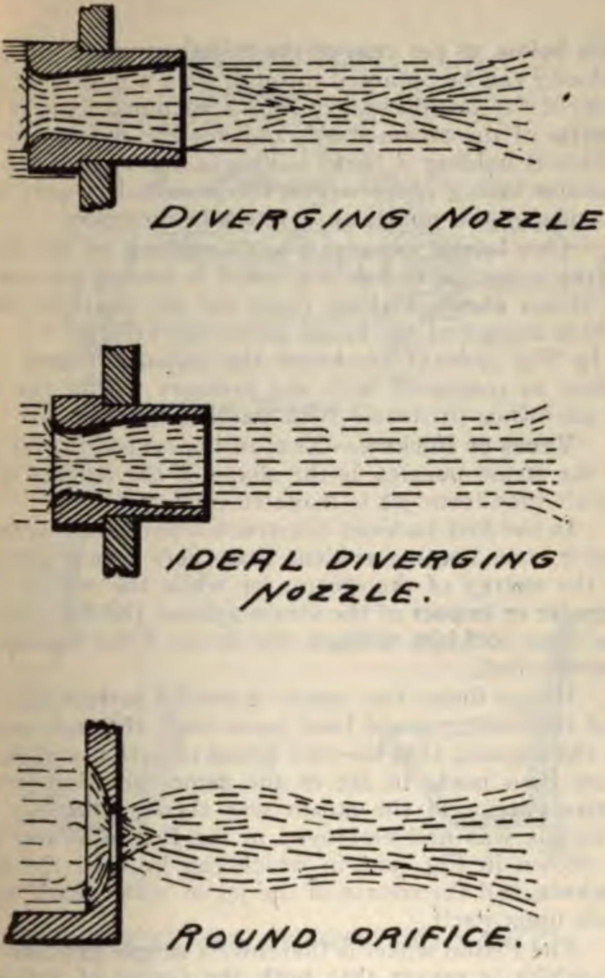
By **static** pressure is meant pressure in **equilibrium**, such as the steam pressure in a boiler which is a force in **equilibrium** so long as it is **confined** in the boiler, but takes the form of **kinetic** energy upon flowing through the pipes. **Kinetic** energy is therefore the energy of a **moving body,** and is always **equal** to the product of one-half its mass into the square of its velocity.

As steam can do no work **without** expansion, and as the steam turbine derives its power from the **kinetic** energy of the expanding steam, it can readily be seen that the **first essential** of a successful steam turbine is the proper expansion of the steam to produce, not **static** force, as in the piston engine, but **kinetic** energy in the form of high steam **velocity.**

The **efficiency** of a turbine, therefore, depends upon the **velocity** of the flowing steam which is often as high as 3000 or 4000 feet per second, and this velocity depends upon: (1) the **difference** between the **initial** or boiler pressure and the **discharge** or exhaust pressure of steam; and, (2) upon the **shape** of the orifice or nozzle through which the steam is discharged.

It is only in the last few years that it has definitely been determined how much the shape of the nozzle has to do with the velocity or flow of the steam. It is mostly due to this lack of knowledge that the development of the steam turbine has been so **slow.**

It has recently been ascertained that the **maximum** flow of steam through a **rounded nozzle,** such as shown in Fig. 300—(1) is 1500 feet per second, **irrespective** of the discharge pressures. When the discharge pressure



Types of Steam Nozzles, showing shape of Steam Jets.

Fig. 300—(3).

falls **below** 58 per cent of the initial pressure, no greater velocity can be obtained through such a nozzle or orifice, even if the jet discharges into a **vacuum,** since it is the **inertia** of the steam itself, and not the **outside** pressure which is holding it back. This is due to no further expansion taking place within the nozzle, but only on the outside of the nozzle in a **laterally** direction.

This **lateral** expansion adds **nothing** to the velocity of the steam, as it does not assist in forcing the particles of steam **ahead,** making room for the particles **behind,** which energy of the steam generates velocity.

In Fig. 300-(1) is shown the initial pressure of the steam as compared with the pressure within the **throat** of an orifice or nozzle with **parallel** sides.

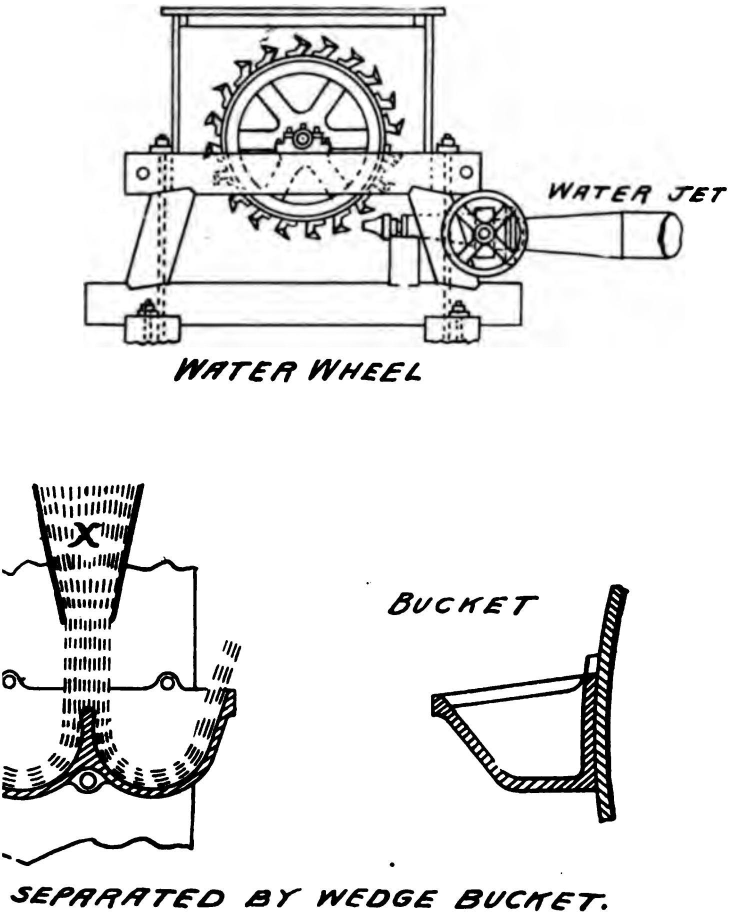
Vanes or Buckets.—Next in importance to the shape of the steam nozzles, is the shape of the surface against which the steam jet is made to imping.

In the first turbines constructed **flat** vanes were used, but it soon became evident that there was a great **loss** in the energy of the steam, for while the energy of the **impulse** or **impact** of the steam against the flat surface of the vane could be utilized, the force of the **reaction** was entirely lost.

It was found that where a curved **surface** was used, and the steam turned back upon itself through an angle of 180 degrees, that the two forces of action and reaction were then made to act in the **same** direction, and the **entire** energy of the steam was then available. This principle was first employed in the **Pelton Water wheel** as shown in Fig. 300, in which can be seen the **curved buckets,** and the course of the jet of water made to flow back upon itself.

The Pelton wheel is therefore a **simple impulse wheel** by which is meant that **both** the forces of action and reaction, which forces are always equal, are fully utilized, less the frictional resistance.

Such vanes or buckets were first employed by **De Laval** in his **steam turbine,** and hence it is known as a



The Pelton Water Wheel.

Fig. 300.

simple impulse steam turbine, differing only from the Pelton water wheel, in that De Laval used **divergent** steam nozzles instead of a **parallel** nozzle as employed by Pelton.

Upon the **shape** of the vane or blade depends the amount of the steam energy that can be utilized.

As we have seen, should the vane or blade be so curved as to change the course of the flow of the steam, making it flow back upon itself in a parallel direction, then **both** the momentum of the impulse and the force of the **reaction** is utilized, and it is purely an **impulse** turbine.

Now, should the vanes or blades be only **partially** curved, so as not to be **symmetrical,** not changing the course of the steam so as to flow back upon itself as above explained, then the force of the **reaction of the** steam alone is utilized, which causes a loss in the Kinetic energy or velocity of the steam. When such vanes or blades are used, with other changes later explained, the turbine is called a **reaction** turbine.

Progress.—Mr. Parsons produced in 1884, the **first** commercial **reaction** turbine. It developed 10 horse-power and ran at 18,000 revolutions per minute. With steam at 92 pounds pressure and running non-condensing it consumed but 35 pounds of steam per horse-power hour. In 1888, he built a 50 horse-power turbine running at a speed of 7,000 revolutions per minute, and soon after, one of 200 horse-power running at 4,000 revolutions per minute. This machine gave results in steam economy comparing favorably with those then obtained with good piston engines.

Description of Modern Steam Turbines.—The following description is, of the **three** most successful turbines in this country, each of these turbines having its **own field** in which the reciprocating engine cannot compete, but no stationary engineer need fear that the steam turbine will ever **replace** the reciprocating engine or eliminate its use in any known field of work.

QUESTIONS AND ANSWERS.

Q. What was the **first** steam engine?

A. A **steam turbine.**

Q. Who invented the **first** steam turbine?

A. Heron of Alexandria about the year 120 B. C.

Q. Describe it?

A. It was a **reaction** turbine consisting of a hollow here mounted on trunnions through which steam was lmitted to the interior. The steam escaped through pes bent **tangentially** to the sphere, as shown in Fig.)8. The force of the escaping steam **reacted** upon the here, causing it to revolve on its trunnions, hence it as called a **reaction** turbine.

Q. Who invented the next known type of steam irbine?

A. Branca, in the year 1629.

Q. Describe it?

A. It was an **impulse** wheel, in which a jet of eam **impinged** upon the flat vanes of a wheel, as shown Fig. 299. The dynamic pressure, or **impulse,** of the eam caused the wheel to rotate, hence it was called ı **impulse** turbine.

Q. What is the difference between an **impulse** and **action?**

A. An impulse is the **momentum** given a body in **forward** direction by some other body striking it; hile **reaction** is a force acting in a **backward** direction lative to the impulse.

Q. Is the impulse and reaction always **equal** and **opposite** directions?

A. Yes.

Q. Can impulse and reaction be made to act in e **same** direction so as to **assist** each other?

A. Yes, by using a **curved** surface, so that the

the **central** point of the cu
force is the **reaction** of th
jet starts to flow **backwar**

Q. In what device
ployed?

A. In the **Pelton wa**
Fig. 300.

Q. Are the essential
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Q. What is the chief
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Q. What is the fund
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A. The utilizing of
steam.

Q. Was the princip

Q. Had the expansive force of steam been utilized in the **reciprocating engine** previous to this?

A. Yes, by James Watt in the year 1782.

Q. Since the year 1782 has there been any important thermodynamical improvements in the reciprocating engine?

A. Only **one,** the introduction of **compound** expansion.

Q. From what does tne **reciprocating engine** derive its **power?**

A. From the **static** force of the steam expanding behind a piston.

Q. From what does the **steam turbine** derive its **power?**

A. From the **kinetic** energy of the expanding steam.

Q. What does the **expansion** of the steam produce in the reciprocating engine?

A. It produces a **force** which presses on the piston.

Q. What does the **expansion** of the steam produce in the turbine?

A. It produces **velocity** in a jet of steam.

Q. How **great** is this velocity?

A. Often from 3,000 to 4,000 feet per second, that is, 35 to 45 miles per minute.

Q. Upon what does the **velocity** depend?

A. Upon the **difference** between the **initial** and **discharge** steam pressures, and upon the **shape** of the orifice or nozzle through which the steam is discharged.

Q. What is the **maximum** flow of steam through a rounded orifice, such as shown in Fig. 300—(1)?

A. 1,500 feet per second, irrespective of the difference of the initial and discharge pressures. This is true whenever the **exhaust** pressure bears a ratio of

58 per cent to the initial pressure, called the **critical** pressure, which applies to all non-expanding nozzles.

Q. Why is this true?

A. Because the steam is free to expand in **all** directions, hence its energy is dissipated, producing no **velocity.**

In consequence, the particles of steam issuing from the orifice **hold back** other particles, thus **decreasing** the velocity of discharge.

Q. How can this trouble be overcome?

A. By the use of a **diverging** nozzle as shown in Fig. 300—(2). In such a nozzle the steam expands to the lower pressure **within the nozzle itself,** causing the steam to be discharged in the form of a solid cylindrical jet, equal in diameter to the **outlet** diameter of the nozzle. This permits the steam to escape at the velocities the succeeding expansions will give it.

Q. Upon what then does the **velocity** of the steam yet depend?

A. Upon the number of expansions given it, that is, the **energy** and not upon the **pressure** in the boiler.

Q. What is it that prevents **all** the steam in a boiler escaping **at once** upon any valve on the boiler being opened?

A. The **inertia** of the steam, that is, its inclination to remain in its present state or condition.

Q. Does it take **energy** to set steam to flowing through a pipe, a valve or any other orifice?

A. Yes, just the same as it does to get any mass in **motion** when it is at rest.

Q. Can **greater expansion** be obtained from the steam in the reciprocating engine, or the steam turbine?

A. In the **steam turbine.** With the best reciprocating engines the steam is not expanded more than **20 times,** while with the steam turbine **100 expansions** are

not uncommon. To obtain as many as 20 expansions, the low pressure cylinder of an engine must be made of enormous size, while to obtain 100 expansions in the steam turbine, it is only necessary to make a slightly different nozzle, or add two or three more rotars or wheels.

Q. Into what two general classes may both water and steam turbines be grouped?

A. Into impulse and reaction turbines. This classification is not strictly correct, as all practitcal turbines are operated both by the action and reaction of the working fluid.

Q. Do the modern types of steam turbines differ essentially from the Heron and Branca turbines?

A. No. they are but the prototypes of these first two turbines.

Q. What were the principal defects in the Heron and Branca turbines?

A. No proper provision was made for the expansion of the steam, also improper construction of the blades; therefore, but little of the heat energy of the steam was converted into kinetic energy.

Q. What are the two chief requisites for a successful steam turbine?

A. As much of the heat energy as possible must be converted in kinetic energy, and this kinetic energy then utilized in an efficient manner. Second, the turbine must be capable of perfect speed regulation without a too great loss of efficiency.

Q. Who first embodied these requirements in a practical steam turbine?

A. Gustaf De Laval in the year 1883, and C. A. Parsons in the year 1884.

Q. What are the fundamental principles of the De Laval steam turbine?

A. This turbine is purely an **impulse** turbine, consisting of a single turbine wheel, carrying **one** row of buckets, to which the steam is delivered in free jets at the highest possible velocity.

The steam is discharged from stationary nozzles, so **tapered** as to increase their cross-sectional area toward the outlet end of the nozzle, and so constructed that the steam is fully expanded down to the pressure in the exhaust chamber of the turbine **before** it leaves the nozzle. In consequence of the extremely high velocity so given the steam, its **whole** available energy is fully transfered into **kinetic** energy.

Q. What are the fundamental principles of the Parsons steam turbine?

A. This turbine is called a **reaction** turbine, but, in fact, is a **combination** of the impulse and reaction principles; **no nozzle** is employed, but there are **alternate** rows of **stationary** guide vanes as shown in Fig. 313. The steam flows between a **fixed** row of directing blades, which serve the purpose of steam nozzles, and a **revolving** row of similar blades, the **revolving** rows of blades acting both in the capacity of buckets and nozzles, the same as in a reaction turbine. Instead of the steam being expanded **within** divergent nozzles, as in the De Laval turbine, the steam progressively **increases** from the inlet to the exhaust in the annular space between the rotating spindle and the cylinder of the walls of the turbine. The entire expansion, which is almost entirely **adiabatic,** i. e. no heat is taken in or given out by the steam cycle, is carried out within this annular compartment, which is exactly similar to a simple divergent steam nozzle, such as is employed in the De Laval turbine, as shown in Fig. 301.

Q. What then are the essential **differences** in the

principles of operation of the De Laval and Parsons turbines?

A. In the De Laval turbines the total available power of the steam is used in a **single** set of nozzles in which all expansion takes place, therefore the steam is discharged at its **highest** velocity upon striking the buckets. As the buckets are made of the **Pelton** type, a complete **reversal** of the jet takes place, the spent steam issuing from the buckets without any velocity. In this way the entire heat energy of the steam is transfered into kinetic energy at the instant it strikes the buckets.

In the **Parsons** turbine, on the contrary, the steam is expanded **within** the **turbine** itself, and in **successive** stages or steps, the pressure being **reduced** a small amount at each step. The **area** of the passages between the fixed and rotating, buckets **increases progressively** to correspond with the expansion of the steam as it is used on the successive disks.

Q. What are the fundamental principles of the **Curtis steam turbine?**

A. This turbine is a **combination** of the De Laval and Parsons turbines. In order to reduce the high steam velocities, the total velocity is **sub-divided** among several stages or is **compounded.** In the **Curtis** turbine **two or more** stages are employed to carry out the total range of expansion from the boiler to the condenser. Each stage comprises a set of expanding **nozzles,** similar to the De Laval nozzles, and a **wheel** carrying more than one row of buckets, similar to those of the Parsons turbine. The steam in each stage is **alternately** accelerated in the nozzles and **retarded** in the blades.

In Fig. 309 is shown a diagram of the nozzles and buckets in this turbine.

Q. How does the **speed** of the De Laval turbine compare with other steam turbines?

A. In the **De Laval** turbine the number or revolutions vary from 10,000 per minute for their larger sizes to 30,000 per minute for their smaller sizes. This speed is **reduced** to about one-tenth on the main shaft by means of accurately cut **spiral gears.**

As the **Parsons** turbine is not purely a **reaction** wheel or purely an **impulse** wheel, the speed is not excessive as in the De Laval turbine, but to accomplish this reduction in speed an **immense** number of blades must be used.

There are about 3,000 buckets in a Parsons turbine to only 350 buckets in a De Laval turbine of the same size. In a 400 K. W. Parsons turbine there are 58 rows each of guide and wheel vanes, or 116 rows in all, aggregating about 30,000 blades.

This turbine operates at speeds from 750 to 3,600 revolutions per minute, no reducing gear being used.

In the **Curtis** turbine owing to the **compounding** of the steam, the energy of the steam is utilized with a comparatively small number of blades, and the speed consequently so reduced that reducing gear is unnecessary.

Q. What **advantage** has the steam turbine over the reciprocating engine?

A. **Compactness,** and the absence of all **internal** lubrication and all **vibration.**

Q. What are its greatest **disadvantages?**

A. The necessity of maintaining a **high** vacuum, and the difficulty in speed regulation without **loss** of efficiency.

Q. What **vacuum** is necessary for the economical operation of all types of steam turbine?

A. 28" of vacuum, which corresponds to one pound absolute pressure.

Q. Why is a vacuum so necessary for the **economical** operation of all steam turbines.

A. To allow as many **expansions** as possible between the initial or boiler pressure and the discharge or exhaust pressure. Also, to **reduce the windage,** which windage always offers considerable **frictional** resistance to the high speed at which turbines must be run.

Q. Is it practical to use **belting** with steam turbines?

A. No, owing to their high rotative speed.

Q. What system of direct driving is therefore used in the operation of electrical generators by steam turbines?

A. The revolving part of the generator is bolted or keyed direct to the turbine.

Q. Is it necessary to **modify** the design of turbine driven generators?

A. Yes, as the voltage of a generator depends on three factors, viz: (1) the **speed** of revolution, (2) the **flux,** (3) the **number** of turns in series **on the armature.** As the turbine speed is so excessive, the armature must be made much **smaller,** and the **field** of the simple **bipolar** type. This greatly reduces the **size** of generators.

Q. What is now adopted as the **standard** for turbine driven generators?

A. **Two** frequencies: **twenty-five** cycles per second for **railway** and **power** service, and sixty cycles per second for **lighting.**

Q. What two well-known steam turbines are in general use in **foreign** countries?

A. The **Rateau** steam turbine, made principally in France and Germany, and the **Zoelly** steam turbine, made in Switzerland.

Q. To what field of work is the steam turbine almost exclusively confined?

A. To the **electrical** field, where large units are employed.

THE DE LAVAL STEAM TURBINE.

Principle.—The De Laval steam turbine consists of a **single disc** with properly formed buckets on the circumference, against which steam impinges at a proper angle. The steam enters a ring-shaped chamber surrounding the casing of the turbine and cast in one piece with it, and from this it enters several nozzles that convey the steam to the turbine buckets. These nozzles are formed in a way that has been found to be most suitable for the purpose, the interior being tapered with the large end towards the buckets. The steam in passing through the nozzles **freely expands,** thereby acquires velocity, gives up its work by impact upon the buckets, and thereby rotates the turbine wheel. It is apparent from this brief description of the process of obtaining the energy from the steam, that if the means of converting the energy of the impact into useful work are sufficiently good the efficiency of the machine will be high. There are many sources of loss to which the reciprocating engine is subject that are not present in the steam turbine, and, of course, to some extent, **vice versa.** In the case of the turbine, the nozzles are not in contact with the turbine buckets, and, therefore, if economy once exists it will be maintained indefinitely.

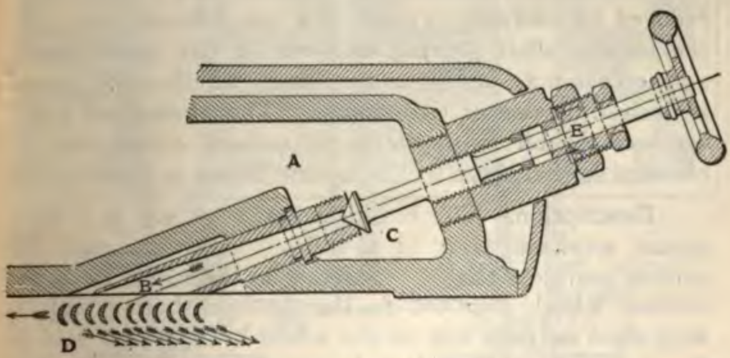
In Fig. 301 is shown a De Laval steam turbine. In Fig. 302 is shown a sectional view of nozzle and valve.

The power of the turbine depends upon the **number** of nozzles in action, and these nozzles can be opened or closed by a hand wheel on each. The machine tested as shown in Table 32, had twelve nozzles, but seven gave the rated capacity. It will be seen from this that the turbine is capable of great overloads.

Regulation of **speed** is accomplished by a throttling valve, operated by a centrifugal governor.

The DeLaval Steam Turbine.

Fig. 301.



Sectional View of Nozzle and Valve.

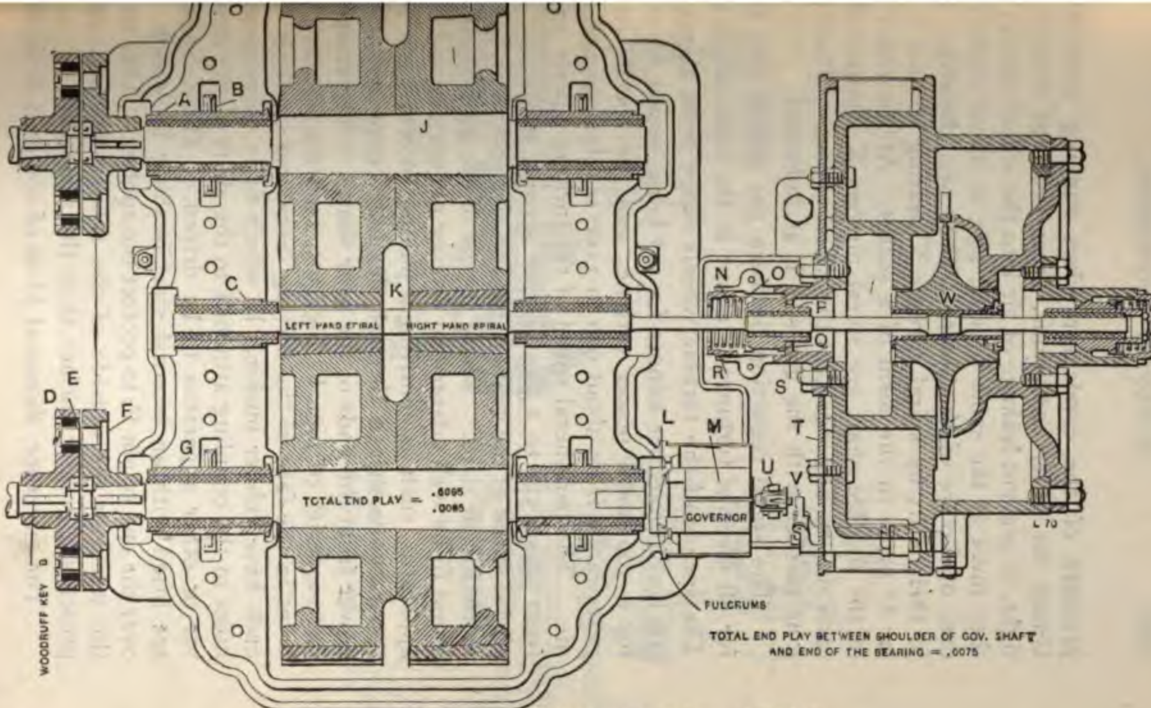
Fig. 302.

In connection with economy of steam and the ability to throw nozzles into and out of action, it is at once apparent that each nozzle performs its function as perfectly when operating alone as when any other number of nozzles is in operation. For this reason the turbine does not change its economy of steam per indicated horse power, if such could be determined, as does a reciprocating engine. There is no "range of temperature" of any importance in the turbine to cause condensation of steam. The principal cause of diminished economy with lighter loads than the rated load is the fact of constant friction with all loads. At overloads there is even greater economy than with the rated load for the reasons that the extra nozzles are of maximum economy and the friction losses are constant.

The turbine used in above test exhausted into a Worthington injector condenser, and the vacuum was measured by means of a mercury column connected into the exhaust chamber of the turbine.

The turbine rotates very rapidly, and the speed is **reduced** by the employment of a spiral speer pinion on the turbine shaft gearing into one or two spiral gears, as the case may be, depending upon whether the power is desired on one or two shafts. The pinion and gears are both double, with the teeth inclined in opposite directions so that there will be no end thrust to either shaft.

Description.—The line drawing, Fig. 303, is a horizontal sectional view of a turbine taken through the turbine and gear shafts. Starting at the right, W is the turbine wheel, attached to the flexible shaft which is supported on each side of the wheel by bearings held in the casing by ball and socket contact. The pressure within the turbine casing is practically atmospheric pressure when running non-condensing, or is equal to the



Horizontal Section of DeLaval Steam Turbine.
Fig. 303.

pressure of the condenser when running condensing. Under the latter conditions, these bearings should be tight, to prevent leakage of air into the wheel casing, and they must at the same time be able to move slightly, in case of flexure of the shaft. They are, therefore, held to their seats by spiral springs N bearing against a collar O made in the form of a socket. At the other end of the flexible shaft are spiral pinions K, supported on each side by bearings C in the wheel casing. These pinions meshes with the gears, I I, as indicated.

The speed reduction between the pinion and gears for all sizes of turbines is about in the ratio of 10 to 1. The speeds of the turbine wheels range from about 30,-000 revolutions per minute for a 7 horse power to 10,600 for a 300 horse power turbine; and the speeds of the gears range from about 900 to 3,000 revolutions per minute. The peripheral speed of the turbine wheels ranges from about 515 to 1,380 feet per second, while the peripheral speed of the gears is 100 feet per second or slightly more, for all sizes. These speeds of the gear shafts are found to be well adapted to driving generators and other apparatus, such as centrifugal pumps, blowers, etc. Such apparatus is driven through flexible couplings taking power from the ends of the gear shafts. The couplings have a series of pins F, Fig. 303, securely fastened into holes in the face of the driving discs, and on their outer ends have rubber bushing E, which fit in corresponding holes in the coupling attached to the shaft of the generator or other apparatus to be driven. These bushings are fitted with an internal steel bushing D, which slips over the end of pin F, to protect the rubber. This brings the wear on the outside of the rubber bushing, which presents a greater surface than the inside.

The governor, shown at M, is of compact design and

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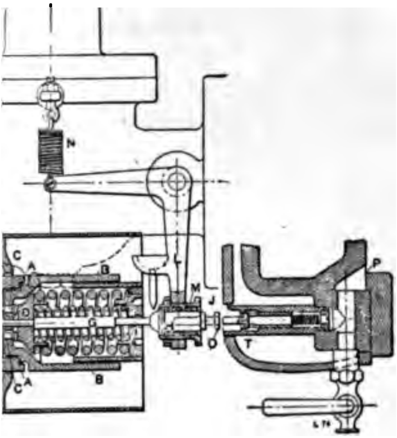
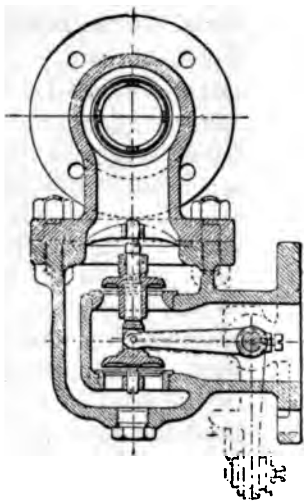


tional View of DeLaval
Governor.

Fig. 304.

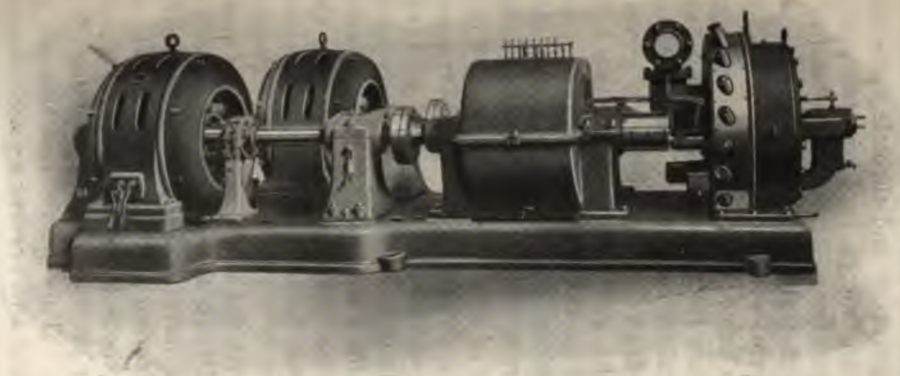


Sectional View of DeLaval
Regulating Valve.

Fig. 305.

is carried by a short shaft made a taper fit in the end of one of the gear shafts. The governor controls a throttle valve, and also, in case of extreme increase of speed, opens a valve admitting air to the wheel casing by means of the lever V, the air acting as a brake or check on the wheel.

Nozzles and Steam Chest.—The first parts to be noted are the **nozzles** which direct the steam against the wheel buckets. They are one of the characteristic features of the De Laval system. These nozzles are arranged about the circumference of the steel casting which serves as the casing for the turbine wheel. The inner end of this casting has a closed annular space, separate from the wheel chamber, which serves as a steam chest for the turbine, as indicated in Fig. 303. The inner ends of the nozzles open into this steam chest, as shown in the sectional view, Fig. 302. A is the steam chest; B, the nozzle; D, the turbine wheel, and C, the valve for admitting steam to the nozzle. The divergence of the nozzles depends upon the steam pressure to be used and also upon whether the turbine is to be run condensing or non-condensing. If the former, the turbine is generally fitting with both condensing and non-condensing nozzles, so that in the event of difficulty with the vacuum the machine can be operated non-condensing with a fair degree of economy. These nozzles are turned to gauge on their outside and reamed to the required taper on the inside. Over 600 reamers of different tapers are kept in the tool room for this purpose. The nozzles are simply driven into place in the casing, but are threaded at their inner ends to facilitate removal by means of a jam nut. The total taper of the nozzles range from 6 to 12 degrees, and they are place with their outlet about ⅛ inch from the wheel blades.



300 H. P., 200 K. W. DeLaval Turbine Alternator.

Fig. 306.

The Governor.—Reference has now been made to most of the principal parts of the turbine, with the exception of the governor and throttle valve which it controls. These are shown in Figs. 304 and 305 respectively. The governor is held in the end of one of the gear shafts by the taper plug K, Fig. 304, and is made cylindrical in form, with its outer shell B B cut longitudinally into two halves which form the governor weights. These weights are fulcrumed at A A and have pins C C which press against a collar D which takes the thrust of the spiral springs located within the governor. The movement of the governor is transmitted through the center spindle G to the bell crank lever L, which is balanced by a spiral spring N. The shaft supporting this lever passes through the valve casting in the inside of which are a pair of arms connecting with a double-seated throttle valve as shown. In the steam pipe above the valve is a wire cylindrical screen, to prevent any large particles of scale or other material likely to damage the valve from passing through. It is to be noted that the connection between the center spindle G of the governor and the bell-crank lever L is a flexible connection, and that at the right is a valve T, which connects through the passage P with the wheel casing. In case the throttle valve should stick and the turbine speed go up, the governor would have power enough to overcome the pressure of the spring at the connection H, and the pin O would strike the spindle of the valve T, which latter would admit air to the vacuum chamber in which the wheel revolves. This would immediately put an air brake on the wheel and prevent an acceleration of speed. If for any cause the speed becomes excessive, this action takes pace. In Fig. 306 is shown a 200 K. W., 300 H. P. De Laval turbine alternator.

[redacted]

TESTS WITH SUPERHEATED STEAM.

ber of Nozzles Open, Eight (8).
ge Reading of Barometer, 30.18 in.
ge Temperature of Room, 83° F.

	Hour.	Steam used per Hour. Lbs.	Pressure above Governor Valve. Lbs.	Pressure below Governor Valve. Lbs.	Vacuum. In.	Superheat above Governor Valve.	Revs. per minute of Generators.	Brake Horse Power.	Steam used per Brake Horse Power per Hour. Lbs.
	A. M.								
2	8—9	4833	208.3	200.6	27.2	81° F.		356.6	13.55
	9—10	4936	207.5	199.3	27.2	86° F.		355.7	13.88
	10—11	5083	207.7	202.1	27.2	91° F.		357.8	14.21
	11—12	4976	208.3	199.4	27.2	88° F.		354.1	14.05
M.	P.M.								
	12—1	4841	207.5	194.3	27.3	82° F.		343.5	14.09
	1—2	4768	206.9	195.6	27.2	75° F.		344.4	13.84
n- v-	8—2	4906	207.0	198.5	27.2	84° F.	750	352.0	13.94

Test of the DeLaval Steam Turbine.

Table No. 32.

TABLE OF RELATIVE STEAM CONSUMPTIONS FOR DIFFERENT LOADS, PER BRAKE HORSE POWER.

SUPERHEATED STEAM.

s	Loads B. H. P.	Relative Loads.	Steam per Brake Horse Power.	Increase for Diminisl Loads, referred to Ma Load.
	352 H. P.	100%	18.94 lbs.	
	298 "	85%	14.35 "	2.9%

THE CURTIS STEAM TURBINE.

Principle.—The principle of the **Curtis Turbine** differs from that of any other type in that it permits the use of moderate rotative speeds, and very compact and simple mechanism. The turbine is divided into **two stages,** each of which may contain one, two or more revolving buckets supplied with steam from a set of expansion nozzles. The work is divided between several stages, consequently the nozzle velocity in each stage is reduced, thereby rendering the nozzle action more efficient and perfect than it can be where a higher initial velocity is imparted. Under this arrangement the energy of the moving steam is effectively given up to the revolving part. The division of pressure between the stages is so arranged as to utilize the largest possible proportion of the energy of expansion. In Fig. 307 is shown the **revolving** buckets, and in Fig. 308 the **stationary** buckets. In Fig. 310 is shown the complete revolving **wheel.** The position of the moving and stationary buckets with relation to the nozzle is shown in Fig. 309.

In other types of turbines the steam finds its way either through a great number of successive rows of buckets without being carried through nozzles or is used in giving velocity in a single set of expansion nozzles requiring either a very large number of buckets and involving other serious difficulties and limitations, or necessitating the use of very high velocities of rotation.

Vertical Type.—As the **Curtis** turbine has a **vertical** shaft, all imposition of weight on cylindrical bearings and tendency to shaft deflection are avoided, as well as all difficulties due to irregularity of expansion or imperfections of support.

Revolving Buckets for Curtis Steam Turbine.

Fig. 307.

Stationary Buckets for Curtis Steam Turbine.

Fig. 308.

Step-Bearing.—The step-bearing at the end of the vertical shaft supports the weight of the revolving part and maintains the revolving and stationary elements in exact relation. It consists of two cylindrical cast-iron plates bearing upon each other and with a central recess to receive the lubricating fluid, which is forced in by steam or electrically driven pumps with a pressure sufficient to sustain the weight of the revolving part. It is apparent that the **entire weight** of the machine is thus carried on a film of lubricating fluid, and that there is no appreciable friction. When the flow of liquid is interrupted the bearing is slowly worn away, but experience has shown that interruptions in the flow seldom cause any deterioration which prevents the continuance of the machine in service after the flow is re-established. The tendency of the bearing in such cases is to wear itself to a new surface so that it operates normally.

In Fig. 310-(1) is shown this step-bearing.

All large steam turbines are necessarily dependent upon **forced lubrication.** A failure of forced lubrication in a horizontal turbine is certain to cause serious trouble through cutting of the shaft or interference with the alignment. In the Curtis vertical type the possibility of any trouble is much reduced, and the simple cast-iron block can readily be replaced at trifling cost.

Clearances.—In consequence of the exact relation maintained between the revolving and stationary elements by the step-bearing, it is possible to operate the turbines with very **small clearances** between the moving and stationary buckets. Experience, however, has shown that the reduction of clearance beyond a certain point is not beneficial, and that clearances less than those which are desirable for economical reasons can be used without mechanical difficulty.

Light Loads and Overloads.—The Curtis Turbine is

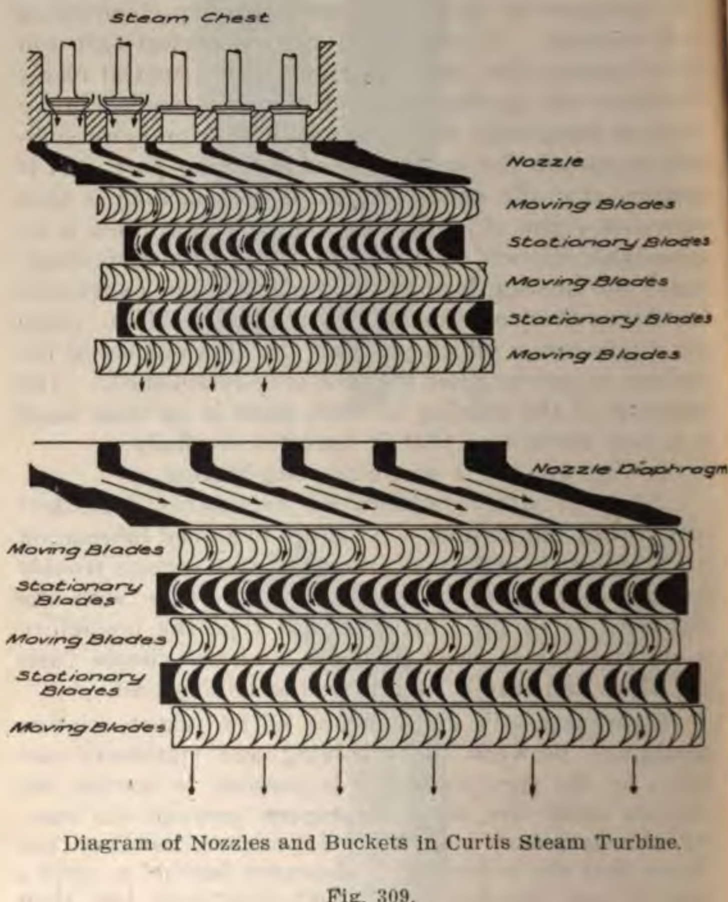


Diagram of Nozzles and Buckets in Curtis Steam Turbine.

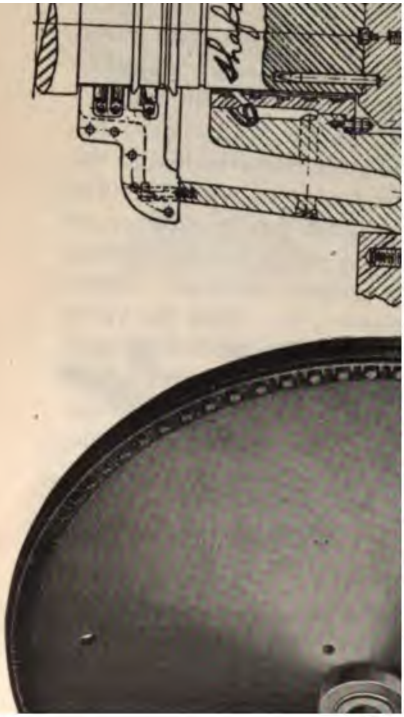
Fig. 309.

governed by changing the number of nozzle sections in flow, and the efficiency of the machine is, therefore, about the same under one condition of load as another, except that friction, windage and generator losses tend to slightly reduce the light load efficiency.

Governing.—The speed of these turbines with variable load is controlled by the **automatic** opening and closing of the original admission nozzle sections, the number of nozzle sections corresponding to the load always being kept in flow. A **centrifugal governor** attached to the top of the shaft imparts motion to levers which in turn work the valve mechanism. There are a number of valves, each communicating with a single nozzle section, or in some cases two or more nozzle sections. These valves are connected to long pistons, by which the valve can be opened or closed by steam. The motion of each of these pistons is controlled by a small pilot valve which is worked by the governor mechanism. The movement of the governor mechanism moves the pilot valves successively, and the main valves are opened or closed by the steam.

Pressure and Superheat.—In the operation of these turbines the steam is **expanded** to a considerable degree before it reaches the first buckets. High temperature in the steam is, therefore, not a source of any practical difficulty, and steam of very high pressure and high degree of superheat can be used. The reduction in steam consumption by superheat or increased pressure is as great in the Curtis Turbine as in any form of steam engine.

Wear on Buckets.—The question is sometimes raised as to the rate of **deterioration** through erosion of the buckets in the Curtis Steam Turbine. A number of experiments have been carried on extending over a pe-



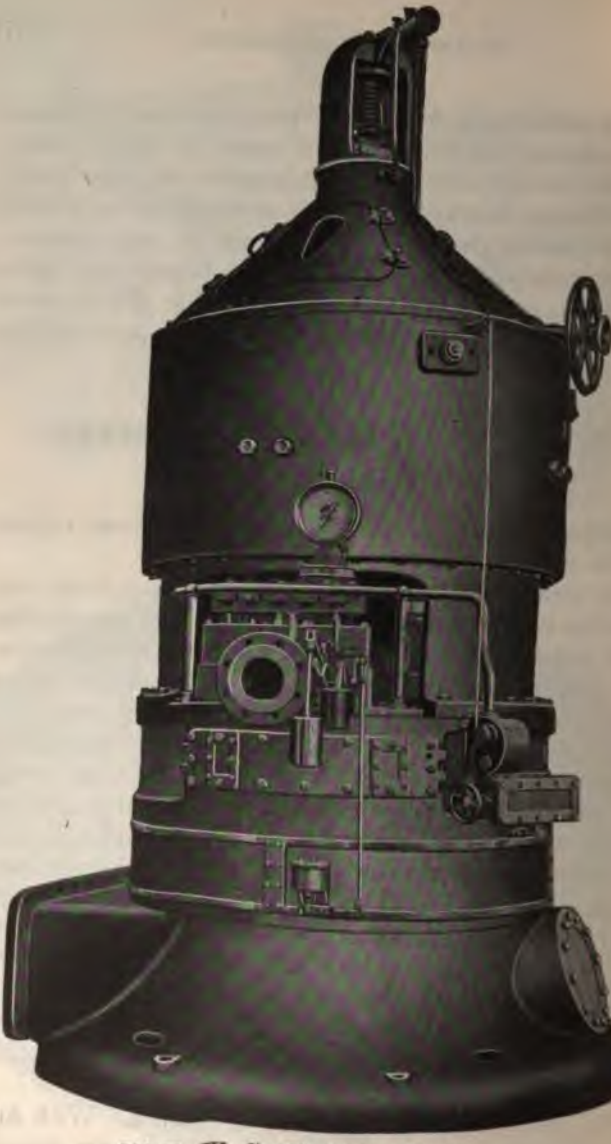
riod of years with a view of ascertaining what the extent of this erosion might be. The result of these experiments has shown conclusively that while the wear varies with different degrees of steam pressure, it is in any event negligible from the standpoint of maintenance. All buckets in the Curtis Turbine can be renewed without difficulty and at small expense. In Fig. 311 is shown a 500 K. W. steam turbine, and in Fig. 312 is shown the complete installation.

THE WESTINGHOUSE-PARSONS STEAM TURBINE.

Description.—A typical Westinghouse-Parsons turbine is shown in section in Fig. 313.

The steam volume progressively increases from inlet A to exhaust B in the annular space between the rotating spindle and the cylinder walls. The entire expansion, which is approximately adiabatic, is carried out within this annular compartment which essentially resembles a simple divergent steam nozzle. There is this difference, however, that whereas in a nozzle the heat energy of the working steam is expended upon itself in producing high velocities of efflux, in the Westinghouse-Parsons turbine the total energy, due to expansion between pressure extremes, is subdivided into a number of steps. In each step the dynamic relationship of jet and vane is such as to secure a comparatively low average velocity from inlet to exhaust, this generally varying from 150 feet per second as a minimum at the high pressure end to about 600 feet per second as a maximum at the low pressure end.

The result is of the utmost importance. With high steam velocities, excessive surface speeds are encoun-



500 K. W. Curtis Steam Turbine.

Fig. 311.

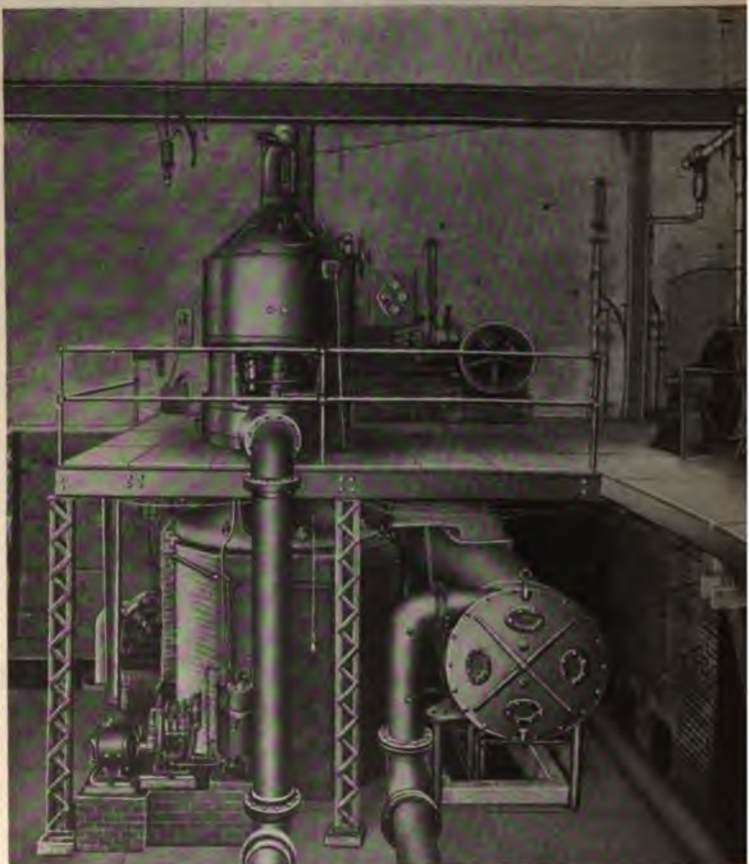
tered, causing serious losses from fluid friction and rapid deterioration of parts from erosion. With low steam velocities, commercial speeds are readily obtained, friction loss is greatly reduced, and the depreciation of the turbine from practically the only source of wear becomes inappreciable.

The expansion of steam at any one element is typical of its working throughout the turbine. Each element consists of a ring of stationary and a ring of moving blades. The former give direction and velocity to the steam; while the latter immediately convert the energy of velocity into useful torque. The total torque upon the shaft is due both to impulse of steam entering the moving blades and to reaction as it leaves them.

A condensing steam turbine in operation affords a striking example of the conversion of heat into work. The temperature of the cylinder falls, within a distance of three or four feet, from 365 degrees Fahrenheit at the high pressure end to 115 degrees at the exhaust end, when working with 150 pounds steam pressure and 27 inches vacuum. These temperatures remain constant during operation. There is no alternate condensation and re-evaporation as in the piston engine.

Construction.—The Westinghouse-Parsons turbine in effect consists of but two essential elements—a casing, stator or stationary part, and a rotor or rotating part. A brief detailed description follows:

Rotating Element.—The rotating element is built up of cast-steel drums carrying rows of blades or vanes, these being mounted on a steel shaft, as shown in Fig. 314. These drums are arranged in three steps of increasing diameters, but the selection of three diameters is merely for mechanical convenience. Provision for



Complete Installation of a 500 K. W. Curtis Turbine Generator.

Fig. 312.

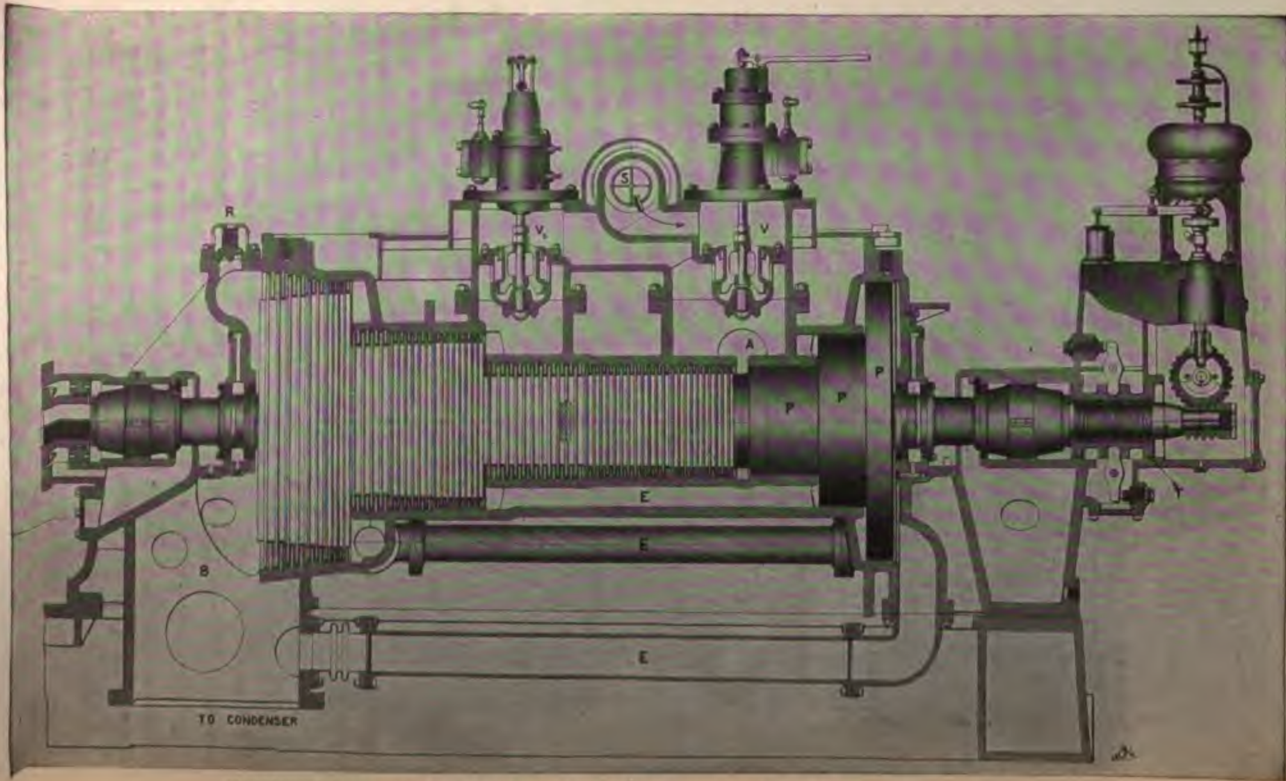
[redacted]

the proper expansion of steam might be made whether there be one or several diameters. If, however, a speed and diameter of rotor be selected that would permit of a convenient size of blades at the outlet, those at the inlet would become inconveniently small, and vice versa. By varying the drum diameters at several convenient points, the proper velocity relations between steam and vane may be preserved, and at the same time the number of different sizes of blades may be reduced to a minimum.

In Fig. 313 the construction is shown as follows:

Opposed to the three sets of blades the spindle also carries three rotating balance pistons P, each of such diameter as to exactly balance, by means of the passage E, the axial thrust of the steam against its corresponding drum of blades. These balance pistons revolve within the cylinder with a close fit, but are not in mechanical contact. The adjacent surfaces are provided with frictionless packing rings which offer so devious a path for the steam as to make leakage past them inappreciable. The shaft also carries a small thrust, or, more properly, adjusted bearing T, whose sole function is to maintain the normal mechanical clearances between the rotating and stationary blades. These clearances may be conveniently large without lowering the efficiency. In actual practice they are never less than one-eighth inch, and in large blades are as much as one inch.

Casing or Stationary Element.—The interior proportions of the casing conform to the several diameters of the rotor and its parts. Around its inner surface are fixed rings of blades which alternate in position with the rings of revolving blades upon the rotor, and are of reverse pitch. The cylinder is divided along a horizontal plane so that by simply lifting the cover all the working parts are exposed to view as shown in Fig. 315.

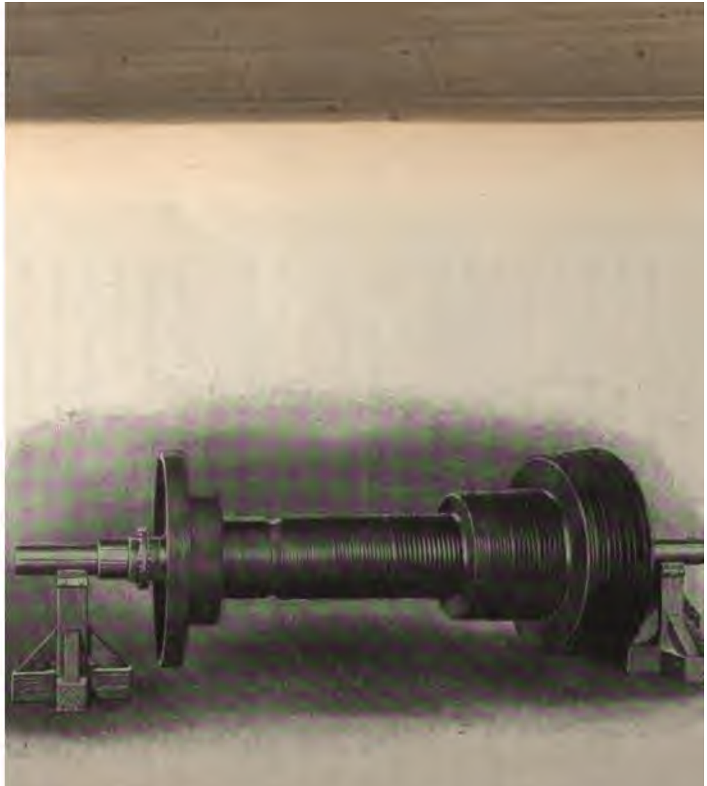


Sectional Elevation of a Typical Westinghouse-Parsons Steam Turbine.

Blades.—The precise curvature and arrangement of the blades is the result of both theory and exhaustive experiment. The blades are so assembled as to admit of great ease of repair, and by a calking process which holds them so firmly to the body of the rotor that they will pull in two before they can be drawn out by force.

Glands.—Frictionless glands are provided at the ends of the casing or stator to prevent the escape of steam or the influx of air into the turbine at the point of entry of the shaft. Air leakage is particularly detrimental in cases where it is desirable to maintain a high vacuum. The **water sealed glands** used in the Westinghouse-Parsons turbine effectively prevent this leakage, and, further, require no lubrication. It is impossible for any oil from the bearings or the lubricating system to find its way into the steam spaces. There are no rubbing surfaces in these glands, and experience has demonstrated that wear is negligible. The water used for sealing them is small in quantity and is not wasted, as, after serving its purpose, it may be returned to the feed water system.

Governor.—In Fig. 316 is shown a complete diagrammatic arrangement of the **governor mechanism.** Steam enters the turbine in **puffs**,. not in a continuous blast. Speed regulation is, therefore, accomplished by **proportioning** the duration of the puffs to the load. This is done by means of a small pilot valve actuated directly by the governor and which controls the steam supply through the main poppet admission valve. When the turbine is in operation the main poppet valve is continually opening and closing at uniform intervals, but the periods during which the valve is allowed to remain open are proportioned to the load on the turbine. At light load the valve opens for a very



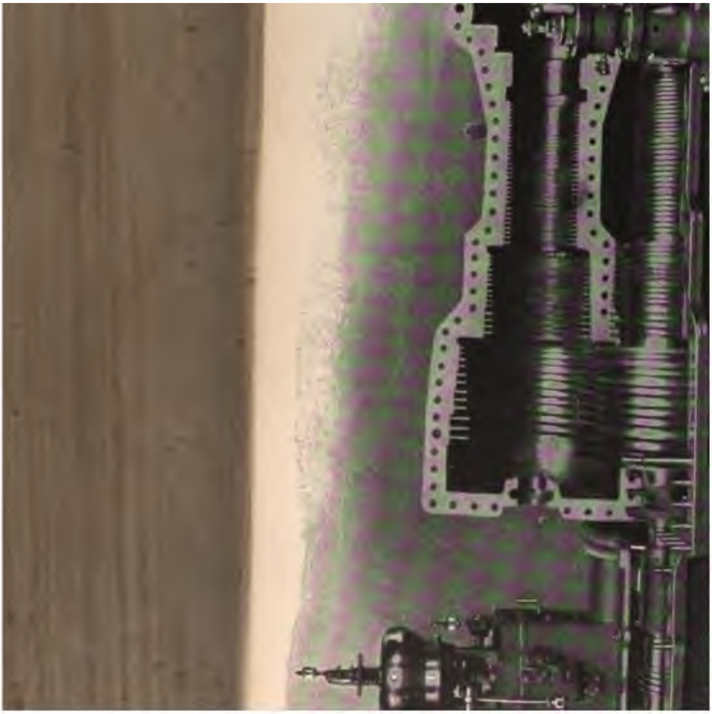
Rotor of Westinghouse—Parsons Steam Turbine.

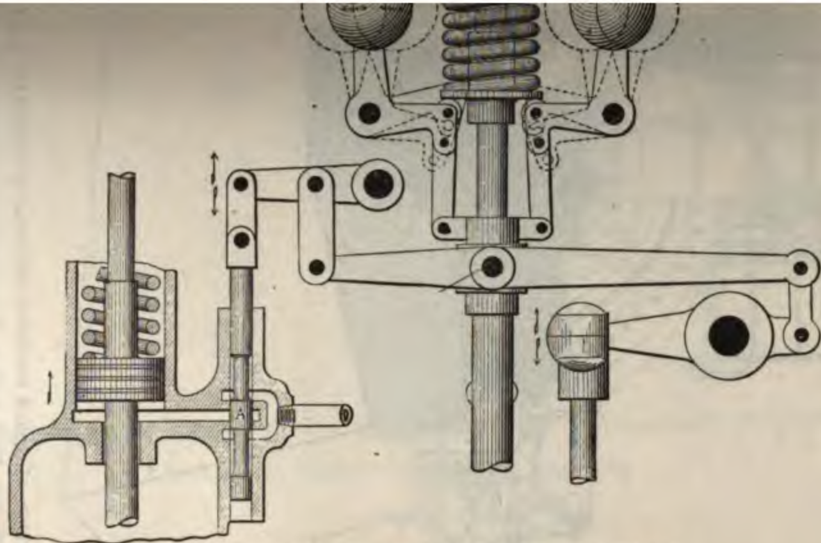
short period, and remains closed during the greater part of the interval. As the load increases the period lengthens until finally, at about **full load**, the valve does not reach its seat at all and continuous pressure is obtained in the high pressure end of the turbine. On the load becoming further increased an auxiliary or secondary valve begins to open and to admit steam to the annular space at the beginning of the intermediate drum of the rotor where the working steam areas are greater. This increases in proportion the total power of the turbine. The operation of this secondary poppet valve is the same as that of the main admission valve, so that the governor automatically controls the power and speed of the turbine from no load to such overloads as are usually beyond the limits of generating apparatus built on normal ratings.

Lubrication.—In the Westinghouse-Parsons turbine the bearing surfaces are so liberally proportioned that the entire weight of the rotating element is supported upon a fluid film of oil through **capillary action alone**, and without the use of oil under high pressures. A small pump driven from a worm gear upon the shaft circulates oil through a closed lubricating system, comprising in the order of their arrangement: pump, oil cooler, bearings and reservoir.

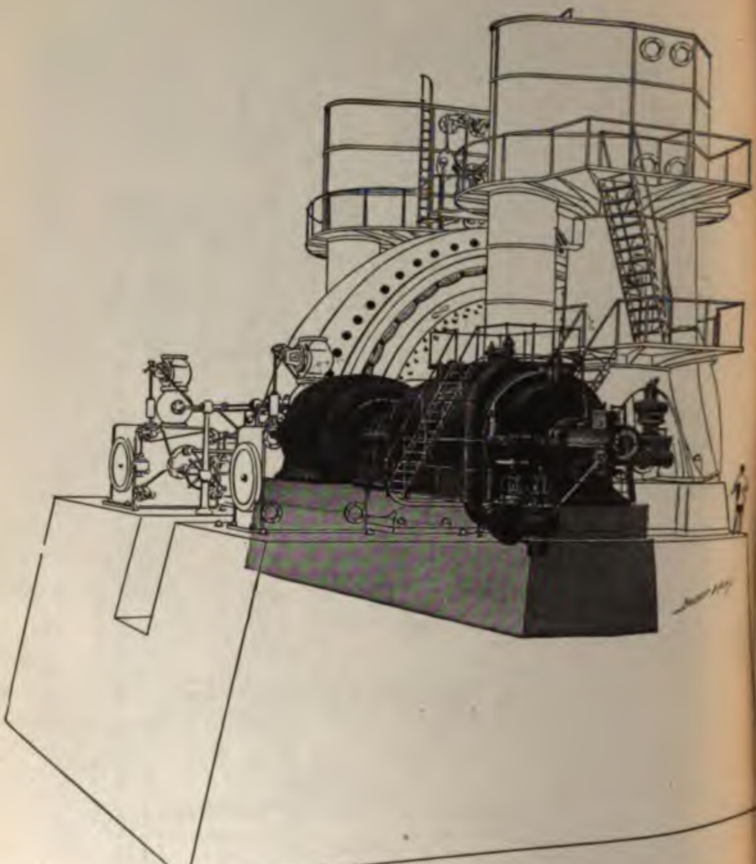
In Fig. 317 is shown a **comparison** of the space occupied and size of foundation of a modern **engine unit** and of a Westinghouse-Parson's **turbine unit** of similar rating and overload capacity.

In Fig. 318 is shown a sectional view of a **complete turbine house.**





Governor Mechanism of the Westinghouse-Parsons Turbine.
Fig. 316.



Comparison of Space occupied and size of Foundation of Modern Engine Unit and a Westinghouse—Parsons Turbine Unit of Similar Rating and Overload Capacity.

Fig. 317.

Load Kw.	Steam Pressure (Gauge)	Superheat °F	Gross Flow Pounds Per Hour	Condenser Leakage, Pounds Per Hour	Back Pressure Inches Mercury	R. P. M.	Water Rate—Lbs. Per Kw Hr.	
							Actual	Reduced to 150° Superheat, 1½ in. Back Pressure, 175 lbs. Steam Pressure
3340	171	151	56690	1070	.89	500	16.66	17.29
5940	169	180	98370	950	1.72	"	16.40	16 55
2920	172	158	50930	1050	1.08	"	17.08	17.61
4860	179	180	81550	1700	1.55	"	16.50	16.81
7525	175	147	130200	820	2.09	"	17.19	16.91
4950	180	171	80570	220	1.48	"	16.23	16.55
0	178	150	3520	220	1.40	"	... ...	. .....

5000 K. W. Curtis Turbine Generator Test.

Table No. 34.

SUMMARY OF TABLE

500 R. P. M.

150 Degrees Superheat.

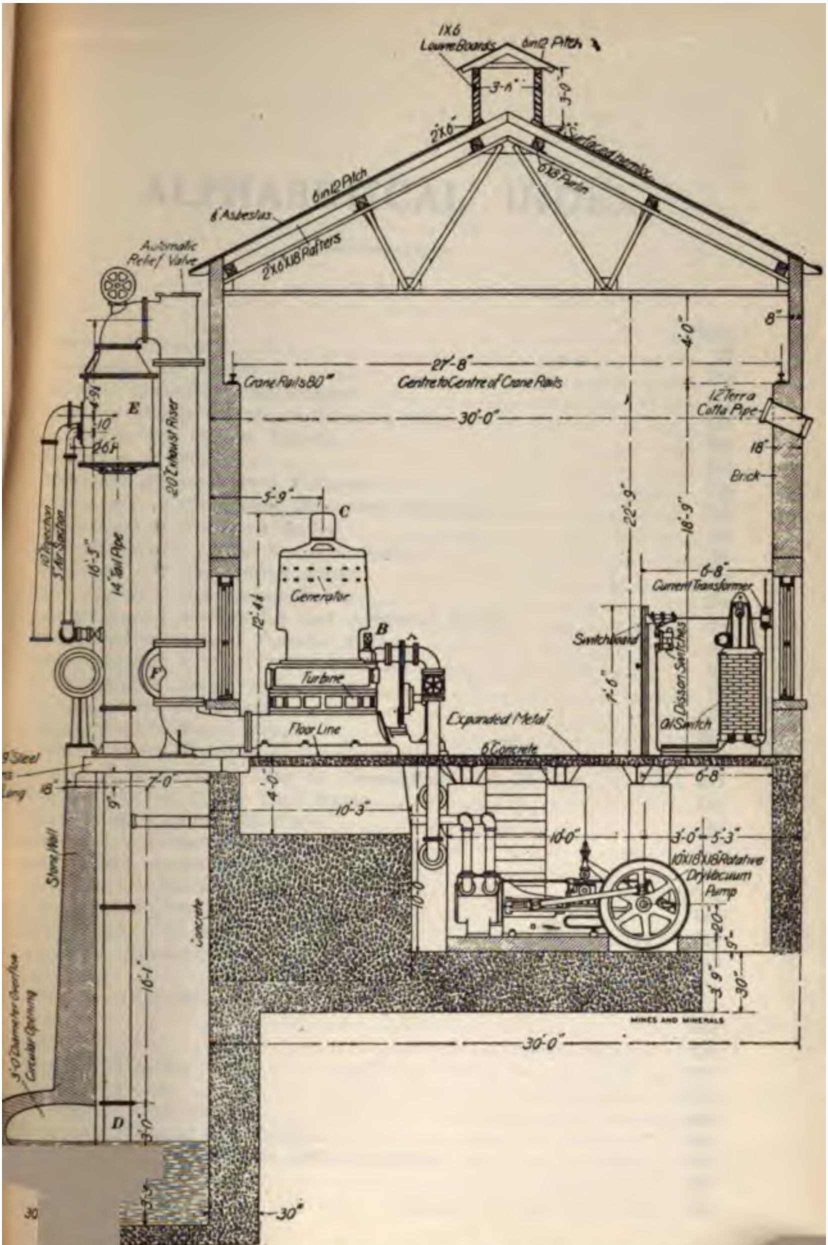
1½ Inches Back Pressure.

175 Steam Pressure (gauge).

		LOAD		WATER RATE
2500	K.W.	(½ Load)	......	17.74
3750	"	(¾ ")	......	17.08
5000	"	(Full ")	......	16.62
6250	"	(1¼ ")	......	16.52
7500	"	(1½ ")	......	16.90

5000 K. W. Curtis Turbine Generator Test.

Table No. 35.



Sectional View of a Complete Turbine Power House.
Fig. 320.

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